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WATER-POWER ELECTRICAL PLANTS IN THE UNITED STATES.

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In presenting to you to-night a paper on "Water-Power Electric Plants in the United States," it is my purpose to show you the great importance of the development of this great branch of our natural resources, and to describe and illustrate a few of the more important plants, and give you the benefit of some statistics gathered by personal correspondence with those directly in charge of over 300 plants. The illustrations cover almost the entire field, and show the perfection attained by the unparalleled genius of American minds in the production of suitable machinery to meet all the different requirements imposed, no matter what are the conditions.

For many centuries man has patiently and earnestly sought to control the vast powers of nature, so that they

shall do his bidding. Human genius has triumphed, and now on the eve of the twentieth century an enlightened world gazes in wonder and admiration while Americans harness the power of their greatest rivers, convert this power into electricity and transmit it with commercial success to distant mining or manufacturing centers.

The application of water as a power for driving mechanical devices is supposed to have been attempted in Rome, about the time of Augustus, 63 B.C. to A.D. 14. During the succeeding centuries various machines have been originated for the utilization of water-power, and recent years have witnessed a most rapid and wonderful progress in their development. The old power-wasting water-wheels of various types have been superseded by turbines for ordinary heads of water, and wheels of the Pelton and Impulse types for extraordinary heads.

The first transmission of electrical power for industrial purposes was accomplished in 1878, at Sermaize, a short distance from Paris, France. The dynamos in this instance were driven by steam engines. Shortly after this demonstration of the practicability of the transmission of electricity, followed the application of water-wheels for driving dynamos.

In the United States there are now nearly 500 electric plants operated by water-power, or water-power and steam combined. Notwithstanding this, there are many hundreds of fine water-powers totally undeveloped, or only partially developed, which would yield handsome returns on the cost of improving them and utilizing their power for the generation of electricity. Some are more favorably situated than others, but nearly all of them of any commercial importance can be developed.

The immense advantages of electrical development are its cheapness, the flexibility and divisibility of the power, and the ease with which it can be transmitted from the point of generation to the point of utilization.

As a power producer the stream must be reasonably steady in the quantity of its discharge. This can be readily determined by pursuing the accurate methods employed in stream measurements by the government hydrographers.

Having ascertained the fall, and the quantity of discharge, the amount of power that is available is readily determined. The next problem is the disposition to be made of the power when it is developed. This is often known in advance, but in some cases the power owners are confronted with many difficulties. The location of the power may not be suitable for a manufacturing site, and should it be desirable to transmit the power to manufacturing centers, existing power and light companies may own franchises which give them exclusive control of the territory. It is not always an easy matter to induce manufacturers owning expensive steam plants to discard them and substitute electricity, although they know it to be cheaper, more reliable, cleaner and generally safer than steam.

The problem of water-power development is, as a matter of course, one of dollars and cents, and the main question is, will the income be sufficient to pay a reasonable per cent. on the investment, over and above general and operating expenses, taxes, maintenance and repairs and depreciation? This question is referred properly to the engineers in charge of the prospective development. The development naturally divides itself between the expert in hydraulics and the expert in electricity. To these experts it remains to solve all the varied and sometimes exceedingly difficult problems that are presented. The machinery for these plants must be constructed to suit the conditions imposed, and the conditions are the unknown quantities which enter the equations and are only solved by experienced engineers. The up-to-date manufacturers of water-wheels and electrical apparatus employ the best of engineering talent, and this talent is at the disposal of those contemplating the construction of water-power electric plants. Upon the engineers devolve the selection of the site for the dam and power-house, and the preparation of plans and specifications for their building and equipment. The kind of dam and its location depend largely on the character of the stream, the shape and geological structure of its sides and bottom, and also the topographic features above and below the prospective site. Of course, dams are

constructed to withstand extraordinary freshets and injury from ice and floating *débris* of all kinds, and of a height that will not cause disastrous results to surrounding property from overflow or backwater. Proper protection is afforded canals, waterways and penstocks leading to the power-house, and ample provision made to keep sand and other detritus from entering the water-wheels. Local conditions are also important factors in the selection of the site for the power-house. When practicable, it is located as near as possible to the source of power, so that the expense for canals, flumes and penstocks will be reduced to a minimum.

The plan of the power-house depends largely upon the style of water-wheel used and the method adopted for delivering the water to the wheels and carrying away the discharge water, the connections between the water-wheels and generators, and whether the plant has additional or reserve steam power. The building and foundations for wheels and generators must meet every requirement of strength and solidity. The entire construction must also be fire-proof. No power-house is complete without a travelling crane.

Recent construction shows a very commendable desire on the part of engineers to standardize the building plans and machinery as far as practicable. The location of switchboards, transformers and outgoing wires are matters of detail for the engineers to decide. Currents of high voltage require extraordinary care in the placing and insulation of transmission wires, and the best methods in use will be shown later.

There are at present two styles of water-wheels in general use in the United States for dynamo driving, viz.: turbines and impulse wheels. As a rule, the use of turbines of the vertical and the horizontal style is confined to powers of ordinary head, where the water is plentiful. The impulse wheels are a necessity under opposite conditions. There are, perhaps, some exceptions to this statement, but I do not think them sufficiently numerous nor important to be cited at this time.

Both styles of water-wheels require the use of water-wheel governors, and this is especially true of plants where there is a variable load on the generators.

There are many different devices on the market for governing water-wheels. Reports from the plants show that the field is almost entirely covered by three governors, viz.: the Replogle, the Lombard and the Geissler. They give remarkably close government under all working conditions, and guard against excessive speed or racing in case of the whole load going suddenly off, as in the case of circuits opening. Only last year you had an able paper read to you on the government of water-wheels, so that there remains little for me to say in connection with this subject, except that Mr. Replogle has perfected and brought out a new governor. It is well known that the voltage drops at the receiving station as the load increases on the line of long-distance transmission plants. This latest governor of Replogle's can be so adjusted as to automatically increase the speed of water-wheels as the load increases, thereby holding the voltage constant at the distant end of the line. In making this advantage possible, he has not destroyed the principle that holds all the gates at several wheels to the same opening, where a number of units are running in parallel.

The kind of generators used, of course, depends largely on the length of the transmission line and the work required. For all long-distance transmission, alternating current generators are used. The voltage of the current generated is raised by transformers and carried at high voltage to the receiving station, and there stepped down by lowering transformers and utilized for light and power purposes.

The pole lines follow roads when practicable, and when run across country the timber is cleared from both sides of the line, so that uprooted trees and limbs broken by storms will fall clear of the line. The poles and cross-arms are of selected timber. The poles are firmly planted and securely braced at curves. Special high voltage insulators are used. The transmission wires are bare copper, the high voltage permitting the economical use of light wires. The wires are spiralled, to prevent induction if telegraph or telephone wires are strung on the same poles.

With this brief general outline of some of the features kindred to water-power transmission plants, I will briefly describe some of the large transmission plants in successful operation in the United States, and attempt, figuratively speaking, to take you through them by means of illustrating the machinery they have in use at the same time it is described. You will kindly bear in mind that some of the ground has been covered by descriptive articles published in technical papers. Nevertheless, it is necessary to make use of some of this material in order to bring out all of the different types of machinery used, the various methods employed in connecting water-wheels and dynamos, and the applications of the power for various mechanical purposes.

THE FOLSOM-SACRAMENTO ELECTRIC TRANSMISSION PLANT.

For data relative to the Folsom-Sacramento electric-power transmission I am largely indebted to Mr. George P. Low and the Sacramento Electric, Gas and Railway Company.

The water-power of the American River is utilized for driving the generators. The various forks of this river rise in the Sierra Nevada Mountains near Lake Tahoe. The water supply of the river presents some peculiar features not found elsewhere, in that the flow of water is derived from new sources at all seasons of the year. In the late spring and summer months the melting snows in the mountains "bridge" over the "dry season," and in the fall, just as this source of supply is on the wane, the rainy season sets in. The foundation of the dam was begun in 1886 by the Natoma Water and Mining Company, and on this foundation, in 1888, the transmission company began the work of completing the dam. The river is confined for many miles by high granite bluffs, and where the dam is erected they form a natural point for the building of such a structure.

The dam contains 30,000 cubic yards of masonry and the headworks about 15,000 cubic yards. The storage capacity of the dam is about 13,000,000 cubic yards of water. The shutter is a trussed timber platform, which

rests in a masonry recess running longitudinally along the top of the center of the dam. When lowered, it is secure from damage by floating *débris*. The shutter is operated by five hydraulic rams.

The sand gates, each covering an opening 5 by 6 feet through the wing dam, are located at the end of the dam to prevent sand or gravel from passing into the canal and causing injury to the water-wheels. The bottom of each gate is 8 feet below the bottom of the canal, and a short distance further down the stream a wall 8 feet high is built directly across the canal. The inlets to three of the gates are tunnel-like openings covering the width of the canal. As the openings are 8 feet below the bottom level of the canal, the water has sufficient flow to remove and discharge heavy substances into the river below. The dam and head-works are built of granite taken from the cliffs on each side of the river. The west bank of the canal is built of granite part of the distance and of earth the remaining distance. The headgates are operated by hydraulic rams.

Two thousand feet down the canal a drop of 7·33 feet occurs. At this point is located the State power-house. This building extends across the canal. The building is 160 feet long, 60 feet wide and 60 feet high, and is built of heavy granite masonry. Six special 87-inch Leffel turbine water-wheels with vertical shafts, geared to bevel pinions to a horizontal shaft overhead, deliver power for electrical and other purposes. About 800 horse-power is now utilized. Without waste the water flows on in a canal built by the Folsom Water-Power Company. At the terminal of the canal is a forebay 150 feet long, 100 feet wide and 12 to 15 feet deep, constructed with ample provision for cleaning out silt and preventing it from reaching the turbines. The hydraulic machinery was all made and furnished by The S. Morgan Smith Company, of York, Pa., and consists of four pairs of 30-inch McCormick horizontal turbines of 1,260 horse-power each. The wheels run under a head of 55 feet at 300 revolutions per minute, and are directly connected by couplings to the armature shafts of the generators. The inlet pipes are 8 feet in diameter, and made

of ⅝-inch steel. Double draft tubes are provided for each set of wheels. Between the four large wheels is the special wheel for driving the exciters. The wheels are made of phosphor-bronze, and each pair is furnished with steel fly-wheels 10 feet in diameter, weighing 10,000 pounds. To each of these four double turbines is directly coupled a 750 kilowatt 3-phase generator built by the General Electric Company. These were the largest constructed up to that time (1888). They are 8 feet 8½ inches high, cover a floor area of 11 feet by 8 feet 8 inches, and weigh nearly 29 tons each. The generators have twenty-four poles, and deliver 3-phase current at 60 cycles per second at 800 volts. There are two four-pole 500-volt exciters, of 30 kilowatts capacity each, either of which can be used to excite all four generators. The generators are carefully insulated from, and securely bolted to, solid masonry.

The current is led through a simple switching board to the bank of step-up transformers on the upper floor of the building. These transformers are of the air-blast type, manufactured by the General Electric Company, and have a capacity of 250 kilowatts each.

The switching board is of Tennessee marble. The two outside panels control the four generators. The center panel contains the synchronizing indicator lamps, the exciter instruments, and main line switches. The generator panels are provided with voltmeters, current indicators and pressure regulators.

Both the primary and secondary coils of all the step-up transformers are worked in parallel, taking current at 800 volts from the generators and delivering it to the lines at a potential of 11,000 volts. Each generator is provided with a separate and distinct circuit from the power-house to Sacramento, and can be worked singly or in parallel. Sturtevant blowers, both at Folsom and Sacramento, each operated by a 2 kilowatt induction motor, furnish air for cooling the transformers when the load is sufficient to cause their heating.

A double-pole line, 22·75 miles long, follows the country road and Sacramento Valley Railroad. The poles are of

cedar, 40 feet long, 12 inches at the top, and 16 at the butt, and are set 6 feet in the ground, 52 to the mile. The cross-arms are braced with angle irons, and are 4 inches x 4 inches in cross-section and 7 feet long. The transmission circuits are supported on double-petticoat porcelain insulators tested to withstand a potential of 25,000 volts. The pole lines each support six No. 1 B. & S. bare copper wires, which effect the transmission at an estimated loss of 10 per cent. at full load. A telephone line is carried on one set of poles. The line is transposed every five poles.

The distributing station is an imposing and substantial two-story fire-proof brick building, and, in addition to the offices of the company, it contains on the ground floor the motor and generator room, in which are located three 3-phase synchronous motors, the electric railway generators, and arc-lighting dynamos. The transmission circuits are led direct from the pole lines to the step-down transformer chamber, in which are located the various transformer equipments.

Three large 250 kilowatt synchronous motors are supplied with energy from 125 kilowatt transformers, which deliver current at 500 volts. The other transformers step-down to 125 volts, the current being distributed over the city on a four-wire system, consisting of three wires for the 3-phase current and a fourth or neutral wire.

The incandescent lighting service is rendered by extensions made between either of the three wires and the neutral, proper care being taken to keep the circuits balanced within reasonable limits. The power service is rendered directly from the 3-phase wiring. Large motors are operated from 500 volt 3-phase wiring; the 125 and 250 volt 4-wire system is used for small motor work and incandescent lighting.

It is hardly necessary to give a recapitulation of the electrical equipment of this very extensive plant, and lack of time has prevented my giving you a more complete description of some of the electrical machinery. The plant was started on July 14, 1895, and has been in successful operation day and night ever since, with the exception of some

weeks, when low water caused a partial shut-down. The useful work performed by this plant can be summed up as follows: It has furnished current for 525 arc lamps, 22,000 incandescent lamps, 1,400 horse-power of motors, and 35 motor cars operating 24·5 miles of single-track and 17 miles of double-track electric railway.

NEWCASTLE-SACRAMENTO TRANSMISSION PLANT.

The Newcastle-Sacramento Transmission Plant is an interesting plant, illustrative of the utilization of a high head of water. This plant is on the Sierra Nevada divide, northwest of Sacramento. At various points on the canal system of the South Yuba Water Company are "drops" or sudden falls. The most important "drop" is one of 464 feet, of which 400 feet is utilized for driving the power plant of the Central California Electric Company.

The water is carried from a reservoir to the power-house, a distance of 6,400 feet, in a 24-inch pipe of riveted sheet steel. The pipe is buried two feet under ground. At the power-house the pipe forks, in a heavy cast-iron Y, into two 15-inch pipes of No. 6 steel, running to the Ys on the Pelton water-wheels. These wheels are of the double pattern, two 48-inch wheels being direct-connected to each of the two 400 kilowatt generators. No automatic water-wheel governors are used, the regulation being effected manually by the switchboard attendant. Not very close attention is required, as the plant runs under a load so evenly laid on or taken off that every change can be anticipated, and even a waste of water avoided. The Westinghouse Electric and Manufacturing Company supplied the entire electrical equipment of this plant, consisting of two alternating current 2-phase generators, two exciters, generator switchboard, step-up transformers, 2-phase 500 volts to 3-phase 15,000 volts, 28 miles 3-phase 15,000 volts transmission line, 15,000 volts receiving switchboard, reducing transformers, 3-phase 15,000 volts to 2-phase 2,000 volts, distribution switchboard, 2,000 volt circuits, and transformers for motors and lights.

The two 400 kilowatt generators are of the inwardly pro-

jecting field and revolving armature type, and run at a speed of 400 revolutions per minute. They generate 2-phase alternating current of 7,200 alternations per minute at 500 volts. The machines are excited by two 15 kilowatt 125 volt exciters, driven by separate Pelton water-wheels. Each generator is connected directly through the switches on the switchboard and fuses to the primary of the step-up transformers, which are connected to transform from 2-phase to 3-phase, and deliver current at 15,000 volts to the transmission line. Four step-up transformers, each of 150 kilowatts, are connected on the Scott system in two pairs of two transformers each for the 2-phase to 3-phase transformation. The pole line is substantial and well constructed. The three wires for the main circuit are No. 4 B. & S. bare copper. The insulators are of the Locke pattern, triple petticoated and made to carry a current of very high potential without cracking or puncturing. They are secured to the cross-arms by steel pins, thus providing a solid support for the wires. Each end of the transmission line is protected by Wurts non-arcing metal lightning arresters. At the sub-station there are three pairs of 75 kilowatt step-down transformers, which receive 3-phase current and deliver 2-phase current at 2,000 volts to the bus-bars of the distributing switchboard. The circuits are supplied with standard transformers for reducing the current from 2,000 volts to 100 or 200 volts as may be required.

In the sub-station are two 50 horse-power induction motors, direct-coupled to 60 light direct-current series machines for supplying arc lights. The motors are supplied by two 75 kilowatt transformers, which deliver 2-phase current at 2,000 volts.

ELECTRO-METALLURGICAL PLANT AT MERCUR, UTAH.

The next feature to be shown will be the application of electricity for operating the machinery of the largest cyanide mill in the world, the Golden Gate, at Mercur, Utah. The current is generated at Telluride, by water-power, and transmitted a distance of 35 miles at a potential of 40,000 volts. The transmission line, which runs through a very

rough and unsettled mountainous country, is of very substantial construction, and the insulators were especially designed for safely carrying current at a very high potential. These are the triple-petticoated glass insulators known as the "Provo," and are made by the Hemingray Glass Company, of Covington, Ky. They were tested under a potential of 50,000 volts, salt water test, before being shipped from the factory, and not one has ever failed to do its duty. Some have been shot to pieces, but no harm other than the burning off of a few cross-arms has ever resulted, and they give entire satisfaction.

Omitting the description of the power plant at Telluride, I will start with the electrical apparatus in and about the mill. All of the electrical apparatus is of Westinghouse manufacture, and the success that has attended the use of this machinery is noteworthy. The loss of electrical energy in transmission is extremely low, being about 5 per cent.

The current is converted in the transformer house from 40,000 volts, 3-phase, to 220 volts, 2-phase. Current is delivered at the mine at $60.00 per horse-power per year, with a minimum consumption of 300 horse-power stipulated. In the high-tension room are the Wurts lightning arresters, the choke coils and the high-tension lines. Special care is taken in insulating.

The ore is hoisted by a 150 horse-power motor, Type C, direct-connected to hoist. The crushers weigh 20 tons each, and have a combined capacity of 1,500 tons daily. They are operated by two 50 horse-power Westinghouse motors, Type C. Another of these 50 horse-power motors operates the roaster and ore converter. A 20 horse-power Westinghouse Type C motor at the same mill drives a centrifugal pump. The plant is operated entirely by 2-phase induction motors, aggregating 700 horse-power, all of Westinghouse Type C.

While illustrating the applications of electricity to mining, I will call attention to the General Electric Company's mining drills and mining locomotives. One of these, of which I show a view, weighs about 6½ tons, and has a drawbar pull of 1,500 pounds on the level at 6 miles per hour.

I show you also the electric hoist in the Free Silver Mine, at Aspen, Col. This is said to be the largest electrical hoist in the world. The electrical equipment consists of one General Electric Company's 100 kilowatt multipolar motor, with a speed of 550 revolutions per minute, and a smaller motor of similar type of 60 kilowatts and a speed of 475 revolutions per minute. The smaller motor can be thrown in gear with the main hoist-motor when the load is unusually heavy.

MECHANICSVILLE-SCHENECTADY POWER PLANT.

The Mechanicsville-Schenectady Power-Transmission Plant has been described with considerable detail in the leading electrical journals, and is, no doubt, by reason of its importance, quite familiar to all present. This plant is only 17 miles distant from the city of Schenectady, where are located the largest electrical works in the world, covering about 130 acres of ground. To this city the water-power of the Hudson River is transmitted electrically, and utilized by the General Electric Company in the manufacture of electrical machinery.

The site for the dam and the power-house, where the banks and bottom of the river are of rock, seems to have been designed by nature to meet the requirements of the most exacting engineer. The water-power is sufficient to produce from 8,000 to 10,000 horse-power for the greater part of the year.

Bluff Island divides the Hudson into two channels. The power-house starts from the west bank and extends out into the river about 215 feet, and is connected with Bluff Island by a concrete dam. On the eastern side of the island is the main dam, which is built entirely of concrete. The up-stream face of the dam is vertical, the down-stream face is curved, and the horizontal apron, 14 feet wide, throws the water off horizontally, and prevents scouring of the toe of the dam.

The abutments are anchored to the rock sides of the river bank and the island. The spillway between the abutments is 800 feet long. In the western abutment are 12 arched

waste-gates, each 4 feet wide and 6 feet high. A floating wooden boom anchored to a line of stone cribs above the dam prevents floating rubbish or ice from choking the waste-gates.

The foundations of the power-house are carried down to bed rock, and the house is carried on steel box web girders resting upon steel I-beam columns. These columns are imbedded in concrete walls carrying arches spanning the tail races and forming the floor of the generator room and the wheel flumes. Division walls form a separate and distinct tail race 22 feet wide for each set of turbines, from which the water can be shut off at will. A thick head-wall divides the house into two parts. The up-stream part contains wheel chambers for seven 1,000 horse-power wheels and two exciter wheels. The down-stream part contains the water-wheel governors and the generators and switchboard. The power-house is 257 feet long; the wheel room is 32 feet wide, and the dynamo room is 34 feet wide. A 20-ton crane runs the length of the dynamo room.

Each main turbine consists of two pairs of 42-inch horizontal Victor turbines, built by the Stillwell-Bierce & Smith-Vaile Company, of Dayton, O. Each set of four wheels is rated at 1,000 horse-power under an 18-foot head. The turbines for each exciter consist of three 18-inch Victor cylinder gate wheels (arranged as a pair with a central discharge and one single wheel), developing a total of 300 horse-power at 259 revolutions per minute. The speed of each set of main wheels is regulated by a Geissler electro-mechanical governor placed on a platform over the turbine shaft and between the head-wall and the dynamo. These governors can move the gates through their full travel in six seconds. Snow governors control the exciter wheel gates.

The generators are 3-phase, forty pole, 750 kilowatt General Electric machines, having internal revolving fields and stationary armatures, wound to deliver 36 ampères of current at a periodicity of thirty-eight cycles and at a potential of 12,000 volts to the transmission lines when running at 114 revolutions per minute. The armature frame is 15 feet

4 inches in diameter and 36 inches wide. The field ring revolves on a shaft 15 inches in diameter, rigidly coupled to the turbine shaft. On each side of the stairway leading to the switchboard gallery are located the exciters. The switchboard consists of nine panels. Five are used for the generators, two for the feeders, one is the total output panel, and the ninth is fitted for the control of the exciters. The details of the switchboard equipment are interesting, but it will take up too much time to enumerate them. In a small house near the first pole are placed double-pole 2,000 volt, short-gap lightning arresters, connected six in series to give the necessary number of spark gaps, which are each $\frac{1}{32}$ inch long. The line consists of three No. 000 B. & S. bare copper wires. The circuits are carried on poles 30 to 60 feet long, 8 inches in diameter at the top. Triple-petticoated insulators are used.

All of the machinery of the General Electric Company in their Schenectady plant is driven by electric motors, so that the change from steam-power on the ground to water-power, developed and transmitted 17 miles, will not necessitate many changes. The steam plant will be retained as a reserve in case the water-power should fail.

The General Electric Company furnished all of the electrical equipment. The Stillwell-Bierce & Smith-Vaile Company, of Dayton, O., were entrusted with the entire development, taking the river in its natural condition and building the plant, turning it over to the operating company in thorough running order, having used throughout hydraulic equipments of their own manufacture.

COUPLING WATER-WHEELS AND GENERATORS—MISCELLANEOUS APPLICATIONS OF ELECTRICITY FOR POWER PURPOSES.

I invite your attention to some views illustrating the methods employed for coupling water-wheels and generators, and also the very wide range in the application of electricity for power purposes.

Of interest are the two 450 kilowatt 3-phase General Electric generators of the Portland General Electric Company, at Portland, Ore. They are driven by vertical turbines

made by the Stillwell-Bierce & Smith-Vaile Company. The weight of the vertical shaft, with the armature, is about 33,500 pounds, and to carry this a system of extra bearings is introduced, one of the ring-thrust type, and the other a hydraulic oil bearing, both supplementing the ring bearings on the armature shaft. They are enclosed in cases filled with oil, delivered by hydraulic pressure, and are surrounded by water jackets. The generator shaft is 29 feet long and 8⅜ inches in diameter. Direct current exciters are used for the 3-phase generators. The direct current for the railway service is obtained by means of rotary converters. Each converter delivers 500 horse-power to the bus-bars of the continuous current switchboard.

At the St. Anthony Falls water-power plant, several 700 kilowatt 3-phase generators furnish the current for operating nearly 240 miles of street railway in the twin cities of Minneapolis and St. Paul. The apparatus seen belted to generator No. 8 is a Lombard water-wheel governor. The Lombard governors are used with the other turbines which drive the generators.

The power plant of the Pioneer Electric Power Company, of Ogden, Utah, is also worth noticing. The water-wheels are of the impulse type, and are directly connected to the generators. Under an effective head of 416 feet the wheels have a capacity of 1,200 horse-power each at 300 revolutions per minute.

A ¼-inch steel pipe 24 inches in diameter conveys water under a head of 1,411 feet (having a pressure of 609 pounds to the square inch) to the 60-inch Pelton water-wheels, which drive the generators of a light and power plant. Three 3-phase 350 kilowatt G. E. generators are driven by the large Peltons, and three small Peltons operate the exciters. The current is generated at 700 volts, and nine 125 kilowatt transformers raise the voltage to 11,500 volts, at which voltage it is delivered to the transmission line.

At the Electric Light Company, Columbus, O., Leffel Cascade 18-inch water-wheels of the impulse type are direct-connected to the generators. The six generators of the Boise Electric Light Plant are driven by a 26-inch double-

discharge Leffel turbine, with six clutch pulleys. Any one generator, or combination of them, can be run at pleasure. The generators of the Skowhegan Electric Company, Skowhegan, Me., are driven by two 56-inch Leffel vertical turbines, which operate under 13 feet of head. The power station of the Electric Light and Power Company, at Raritan, N. J., operated under a head of 13½ feet, is driven by 40-inch wheels of the same make.

A point which I wish to illustrate is that the use of vertical turbines and heavy gearing is necessary when the fall is not great and waste of water is not permissible. Thus, I show you an installation in which the turbines are belted to pulleys on the main-line shaft extending the whole length of the wheel-room and continuing through the partition walls into and along one side of the generator-room of the power-house of the Ponemah Mills, Taftville, Conn. This power-house is located at Baltic, 4½ miles distant from Taftville. The pulleys are put into, or out of, action by clutches mounted with pulleys on quills, so that any one, or all, of the wheels can be applied to driving the shafts.

The belted generators are G. E. 250 kilowatt 3-phase generators, which deliver current to the line at 2,500 volts. At Taftville the 3-phase circuits are led into the basement of the mill, where they drive two 3-phase synchronous self-starting motors. These motors furnish power for driving the 1,700 looms, the lighting plant and three 80 horse-power G. E. railway generators. This was the first important application of electrical power transmission to textile manufacture.

In the Carolinas and Georgia are many valuable water-powers, and capital has been steadily invested in these powers during the last five or six years, and several notable electrical developments have been made.

I have some interesting views which show only a very small portion of the largest and greatest water-power development on earth. You know, of course, that I refer to the enduring monument to engineering skill and genius built at Niagara Falls by the noted engineer, Dr. Coleman Sellers. No hydraulic and electric plant was ever built

where such tremendous engineering difficulties were encountered at every stage of its progress, and yet, thanks to the genius and perseverance of the engineers employed in the different branches of the development, every difficulty was promptly met and perfectly solved. This plant has been very ably written up and profusely illustrated in the edition of Cassiers Magazine for July, 1895, and was made the subject of two numbers of *The Electrical World* in January, 1899.

The speaker here showed a number of views illustrating the exterior and interior of the Niagara power plant.

The Pelzer Manufacturing Company, at Pelzer, S. C., one of the largest manufacturers of cotton goods in the South, has a well-equipped electric-power plant. The transmission plant consists of three pairs of 60-inch turbines, made by the Stillwell-Bierce & Smith-Vaile Company, direct-connected to three 750 kilowatt 3-phase G. E. generators, wound for 3,300 volts. The power is carried three miles to the mills. The motors consist of one 400 horse-power synchronous motor, wound for high potential, fifteen 110 horse power, four 75 horse-power, two 50 horse-power, one 20 horse-power, and four 5 horse-power, a total of 2,530 horse-power. Most of these motors are of the inverted type, and are suspended from the ceiling, and receive current at low potential from step-down transformers, located in the sub-station at the mills. The mills are lighted by 1,200 incandescent lamps, from the same power. The electrical equipment throughout the entire plant was furnished by the General Electric Company.

The electric plant of the Columbia Mills Company, of Columbia, S. C., also deserves notice. Two pairs of 48-inch horizontal turbines, made by the Stillwell-Bierce & Smith-Vaile Company, operated under 26 feet head of water, develop 2,000 horse-power. One 24-inch wheel under the same head develops 190 horse-power, making a total of 2,190 horse-power. This power drives two 500 kilowatt 3-phase generators, direct-connected to the turbines, running at a speed of 108 revolutions per minute. The power is transmitted a distance of ½ mile to the mills, and there drives

1,775 horse-power of inverted motors, and these motors operate all of the machinery of the cotton mills.

These two plants illustrate better than words the advantages derived from the electrical development of water-powers, especially when the powers are utilized for manufacturing raw materials raised at the very doors of the mills. In the cases of these mills in particular, a large saving is made in the cost of power, and the use of individual ceiling motors dispenses with many feet of power-wasting shafting, and also saves a large amount of valuable floor space. The absence of many yards of belting gives better light to the employees in the building, and lessens their chances of being accidentally injured. Another point to be scored is the cheapness of living and the low cost of labor in the locality of these mills.

That this locality is a splendid field for the investor is shown in the interest taken by the Government in having all the water-powers in this section accurately measured. A very complete report has been published on "The Progress of Stream Measurements" by the U. S. Geological Survey. This publication very materially strengthens the views I advanced a few years ago: that this section offers splendid opportunities for a water-power development company. Such a company could buy the best powers and develop them at leisure. The cost of such developments would be exceedingly reasonable, since timber for buildings and pole lines and stone for dams are to be found wherever there are powers. There are many other features worthy of consideration, such as the building of factories for manufacturing many articles that are now brought to this section from a distance. Land about the factories would also be available for town sites, so that the original outlay would be gotten back in a few years.

There is little question but that powers not immediately developed would increase in value more rapidly than interest would accrue if the capital were invested at the present low rates of interest that are being paid on large sums of money.

A few statistics relative to water-power electric plants

may be of general interest, and, since they were obtained after the expenditure of considerable time and labor, I will try and present them in such shape as not to weary you.

In the first place, the method employed for securing accurate and reliable data was by personal correspondence with the electricians in charge of the plants, a list of the plants operated by water-power having been furnished me by the different manufacturers whose machinery was used in the plants.

There are nearly 500 water-power electric plants in the United States, representing an investment of over $60,000,000. The total horse-power represented by water-wheels is over 200,000. The power is furnished for lighting 28,000 arc lights, 845,000 incandescent lights and for operating about 60,000 horse-power of motors. There are over 610 miles of electric street railway operated by water-power electrically transmitted.

The geographical location of the plants shows that the water-powers have been electrically developed in proportion to the powers available. New England has no coal fields, but it seems that Providence has supplied this portion of the country with numerous large water-powers. Of the 312 plants from which I have received reliable data, 115 are located in the States of Maine, New Hampshire, Vermont, Massachusetts and New York. Michigan has twenty-six, California, twenty-five, and Colorado, eleven. The other plants are distributed among the other States.

It seems to be fairly well established that it pays to develop water-powers from 50 horse-power and upward, and that additional steam-power is necessary when the water-power is not sufficient to do all the work, and is not reliable at all seasons of the year. It is a well-settled fact that at the present time power can be profitably transmitted up to 80 miles, and utilized for any purpose for which steam-power has been applied. In mining localities it has made possible the profitable reduction of low-grade ores that could never have been mined had steam been the only power available, owing to the enormous cost of coal and the difficulty of transporting it from the nearest

point on railroads to the mines. In short, we find that our inventors have produced water-wheels, dynamos, motors and transformers of the highest efficiency, that governors regulate the water-wheels with the greatest precision, that insulators are made to safely carry currents of enormously high potentials, and that perfect protection is afforded the electrical apparatus from electrical disturbances caused by lightning.

Not until all electric light and power stations are equipped with total-output wattmeters, and accurate books are kept, showing the exact amount of fuel used and all of the expenses of operating the plants, will satisfactory data be available for comparing the cost of producing current by the two methods—water and steam. When sufficient progress has been made in adopting uniform methods of keeping station accounts, and accurate and reliable data can be secured, it is my purpose to obtain and publish comparative statements showing the cost of producing current by the two methods.

[The subject of the paper was profusely illustrated with the aid of stereopticon views.]

Mining and Metallurgical Section.

Special Meeting, January 25, 1899.

MALLEABLE CAST IRON—Its HISTORY in the UNITED STATES.

George C. Davis.

(*Concluded from p. 144.*)

Moulding sand was obtained from a place between Newark and Elizabeth. For cores, sand from Rockway, Long Island, was used, the binding material being wheat or rye flour. The patterns were usually made from white metal, though iron, brass or wooden patterns were sometimes used. Fewer pieces were moulded on the gate than is now

the practice, as it was thought impossible to run them. For one-inch buckles, from four to eight were placed on one gate, though several gates were moulded in each flask. The flasks were made of sheet iron, circular in shape, and were fastened together with a button and eyelet hole. The castings were cleaned in a tumbler, which was made from a keg strengthened with iron hoops. A door was cut in the side, and holes bored to let out the sand. Iron journals were bolted on the ends. The journal boxes were of wood, and power was furnished by a belt over the center of the keg.

The first annealing furnace was shaped like a beehive and the pots were inserted from the top, which could be removed by a crane. Mill scale was packed around the pots and whole kept at an annealing heat for a week. This type was succeeded by a rectangular furnace, which was run continuously. The floor was laid on an incline and the charging done from the higher end. The whole charge was moved along and pots were thus pushed out at the lower end, hence the name of "Shoving Furnace." This furnace was closed by large bungs, luted at the joints, and held forty-eight pots, which were about 12 x 10 x 10 inches. They had a solid bottom, and after packing were covered with an overlapping tile, inverted, and the joints luted. The fire-boxes were on the side with inlet ports near the top of the furnace, thence the flame went to the upper end, and then down to the flues that led underneath the furnace to a stack near the lower end. Pine wood, charcoal or soft coal was used for fuel. The castings were cleaned in a tumbler with leather and stars. A considerable variety of castings were made, comprising, as a catalogue—a small card,* size 3 x 4

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*S. BOYDEN,

MANUFACTURER OF MALLEABLE IRON CASTINGS,

Bridge Street, Newark, N. J.

Catalogue of Articles.

For Coachmakers.—Coach wrenches; Pole hooks, Crabs and Stops; Tug hooks and Racks; Shaft Sockets & Hold-backs; Swivel-tree Hooks, Tongues, Ferrules and Loops; Coach Body, Door and Footboard Handles; Gig Body, Wing & Dash Handles; Hub Boxes, Bands, Caps and Axle Nuts; Spring, Shaft and other Steps; Perch and Body Wear Irons; Perch, Body

inches, and printed on one side—states, over 1,000 different articles. Among the articles enumerated are "Cavasons for the Spanish market." Judging from this, Boyden was as fully alive to the advantages of the foreign trade as are some of our modern imperialists. It may be necessary to explain that a cavason was a ring with a staple cast on it that could be put on the nose of a horse in order to wrench it and facilitate breaking in. The demand for castings was mainly local, and at first they met the opposition encountered by any new article. The blacksmiths objected to the variable character of the metal and feared it would do away with much of their trade. The prices obtained at first were about 25 cents per pound, but they gradually fell to 8 cents by 1854, and afterwards rose somewhat after the Civil War.

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and other Check Loops; Te, Baggage and other Bolts; Square, Cap and Thumb Nuts, Brace Buckles, Rollers and Shackles; Bow Irons, Joints & Props; Lamp Props, Seat Rails, Te and Connecting Plates; Back Strap Hooks and Plates; Double and Single Footmen Holders, Coach Hinges, Dovetails, Seat Irons, Check Territs, Sand Bands, Linch Pins, Tire Nails, Washers, Boot Loops, Hooks, etc.

For Platers.—Bits, Stirrups, Turrets, Hooks, Hame Turrets, Hame Clips, Links and Rings, a general assortment of Buckles and Tongues to suit; Trace Bolts, Plates and Loops; Crooper, Pad, Saddle and other Loops; Swivels, Dees, Rings and Rivets assorted, Band Screws, Pad Screws, and Nut—also Steps, Buckles, Bits, Handles, Shaft Caps, and Cavasons for the Spanish Market.

For Gunsmiths.—Butt Plates, Guards, Side Plates, Cups, Sights, Loops, Slides, Breech Pins, Triggers, Trigger Plates, Set Trickers, Rifle Boxes, Dirks, Screws and Limbs of Locks.

For Cutlers and Surgical Instrument Makers. Knives, Forks, Spoons, Snuffers, Shears, Scissors, Pincers, Pliers, Tooth Keys, Saw Backs, Spring Boxes, Handles, Screws, etc.

For Locksmiths.—Boxes, Bolts, Keys, Spindles, Staples, Screws and other Limbs; Knobs, Handles, Latches, etc.

For Machinists.—Wrenches, Screw Tools, Lathe Work, Clamps, Parts of Spinning, Weaving and other Machinery.

For Blacksmiths.—Ornaments for Iron Fence, Scrapers, Sash, Blind and Shutter Fastening; Carpenters' Hammers, Squares and Compasses, Garden Rakes, Forks, Hoes and Trowels, Iron and Coffee Stands, Shovels and Tongs, Stove Latches, Catches & Door Handles, Kettle Ears, Trowel Shanks, Limbs of Coffee Mills, and many other things not enumerated. The Collection consists of more than ONE THOUSAND plain and ornamented patterns of Iron articles now in use.

In the early thirties, Otis Boyden, a brother of Seth, had started the Crockett Foundry in Newark. This works was burned down in 1835, in which year the Boston M. I. C. & S. Co. bought out what was left of the Crockett Foundry's equipment and also Seth Boyden's establishment, where they continued in business until 1837, when they failed. Thus Seth Boyden's connection with the malleable iron industry ended in 1835, after continuing nine years, though, as we shall see later, several of his brothers started other foundries. The Boston Company were succeeded by a stock company, which from time to time underwent various changes in membership, until at the present day the place is operated under the firm name of Morris & Barlow. Part of the original building still stands, serving as the wall of the present foundry, though it has been raised several feet.

The extension of the malleable iron industry was very rapid, and several foundries were started in various places at about the same time. Many of the concerns were short-lived, as they suffered from the financial troubles of 1837 and the difficulties encountered by any new process. It is impossible in the time at my disposal to do more than briefly refer to some of the others. There were two concerns in Elizabethport, of which I have been unable to learn very much, except that they were probably started previous to 1840. David Meeker began making malleable iron in Hedenburg's Works, in Newark, in the year 1841, but removed two years later to his present location, where the business is now conducted by S. J. Meeker. The New Jersey Malleable Iron Works was started in 1848 on the spot where the Market Street Station of the Pennsylvania Railroad now stands. At one time there were said to be eight malleable iron foundries in Newark. In 1833 Calvin Adams started a malleable iron foundry at Oak Hill, Greene County, N. Y. A branch of this concern was established at Westmoreland, N. Y., in 1850, under the title, The Oak Hill Branch Malleable Iron Company. The original works at Oak Hill was continued for a few years, when it was moved or sold out to parties who formed a corporation at Coxsackie, N. Y., where they continued in business for some years. The West-

moreland foundry continued for some time as a branch of the Oak Hill Works, but after severing its connection with the parent concern took the name of Westmoreland Malleable Iron Works, under which it is now operated. These works have largely been devoted to such light castings as saddlery and harness hardware, gun and pistol work and steel trap castings. Calvin Adams is supposed to have removed to Pittsburgh, Pa., where he may have started other foundries.

The malleable iron industry in this city was first started in 1833, at Susquehanna and Germantown Avenues, by Stellwagon & Bryant. This works was a small one, employing some ten or twelve moulders—it was probably an offshoot of the Boyden Works in Newark, as at least two of the moulders came from that place. The works' practice, so far as can be learned, closely followed that already described. Carriage hardware, coffee-mills and small articles were the chief products. According to the custom of the times, great secrecy was observed, and for what few details of the business now attainable I am indebted to Mr. John Dessalet, of this city, who was a moulder in these works. Mr. Dessalet, in his ninetieth year, is hale and hearty, and is undoubtedly the only man now living who was connected with them. He states that Mr. Bryant was the practical man of the concern, and carried on many experiments, but none of the men, except one laborer, selected for his ignorance, were allowed in the annealing room. One attempt to add something to the molten iron resulted in an explosion which cost one man his eyesight. The iron was melted in a small air furnace, which ran under natural draft, and could not have been very economical of fuel, as it is stated that flame often showed at the top of the stack, which was 80 feet in height. New Castle coal was imported in considerable quantities. The fire-brick, Stourbridge, also came from England. These works continued some five or six years, when the business was abandoned, though for what reason it is not known.

In Massachusetts the malleable iron business was first established in East Boston, about 1835, by a company incor-

porated with a capital of $100,000, and under the management of Alex. Boyden, a brother of Seth. A younger brother, Frank, was also employed there. This concern only ran about two years, as there was not much demand at that time for machinery castings of malleable iron. The company made stock goods, such as hammers, axes, chisels, etc., very little light cored work being attempted. They evidently followed along the lines of the earlier English works, as large quantities of castings were made under the impression that they were steel. These could not be sold, and, as no dividends were forthcoming, the stock was bought up by a few persons, who crowded out the Boydens. So far as can be learned, the practice in these works differed in no essential from that already described. "Flat Bar" Salisbury pig was used, and the melting was done in two air furnaces, capacity 1,000 and 1,600 pounds, respectively, the latter being considered a large furnace at the time. Flat Bar was the common name for Salisbury iron, but from which of the furnaces it came, or whether it was common to all of them, I have been unable to learn. A cupola was erected, but for some reason did not succeed. It is said that the packing was oxidized with sea water.

In 1837 Alex. Boyden was employed by Frederick Fuller, of Easton, Mass., who at that time was operating the Easton Iron Foundry, established in 1752, to start a malleable iron foundry in Easton. The land and foundry buildings were leased to Boyden for $350 per year. The lease begins, according to the old legal form: "This indenture, made the first day of March, 1837, by and between Frederick Fuller, of Easton, in the county of Bristol, gentleman, on the one part, and Alex. Boyden, of Easton, in the county of Bristol, iron founder, on the other part, witnesseth, etc." Evidently in those days the distinction between an iron founder and a gentleman was sharply drawn. The foundry was continued under Boyden's management about a year, when his interest was bought out by Lincoln Drake, who was the executor of the Leach estate, owners of the Easton Foundry, who had been Fuller's financial backer. Boyden agreed not to establish or help establish any other malleable iron foun-

dry in New England. In 1838 Daniel Belcher took charge, buying out the business ten years later, and continuing it until his death, which occurred in 1890.

I am indebted to George C. Belcher, the present proprietor of these works, for many of the interesting details of the early practice, and feel that I cannot do better than give the account in his own words. He says: "At these works about one-quarter flat bar Salisbury and three-quarters Sterling iron was used, which was valued in the inventory, taken 1840, at $50 per ton. The moulders made their own cores, dumped and trimmed their own castings and helped the melter when skimming the slag from the air furnace, for all of which they received $1.25 per day. The fuel used in the air furnace was Pictou coal, costing $14 per chaldron or thirty-six bushels and pine limbs. The charge was 800 pounds, sometimes 1,000 pounds, and the writer well remembers when the melter, without consulting the boss, had the temerity to put in 1,500 pounds. With what anxiety all watched the furnace for something to happen, expecting the bridge to give way and let the iron back onto the grates or that the whole charge would puddle and refuse to run when tapped. The bottom of the air furnace was made up of quartz mixed with a little clay, and stood about sixteen heats. The quartz was obtained in the neighborhood, and was first calcined in the air furnace and then pounded up. Stourbridge fire brick were in common use at this time in the construction of the furnaces. The annealing furnaces were also run with Pictou coal and pine wood, the firemen firing up every fifteen minutes. The annealing pots were pushed in on rolls at one end of the furnace and pushed out when done at the other end by the introduction of fresh pots." Very soon after he took charge Mr. Belcher built a hard coal annealing furnace, which, while building, was ridiculed by all old hands, including the melter, who was from Newark, but, proving successful, was afterwards claimed by the melter as his own invention. The castings made at first were carriage, harness and stove trimmings, fliers for cotton speeders and fly frames, pump castings, mule fingers, loom forks, keys, axle nuts and shanks for gar-

den trowels. Pipe fittings were manufactured here as early as 1849, and possibly earlier. They were shipped to Walworth & Nason, of New York City, to have the threads cut. The price obtained for axle nuts in 1840 was 12½ cents per pound; stove trimmings, 15 cents per pound. Average price of castings, including cored work, 16⅔ cents per pound, or one shilling. Large speeder fliers, however, brought 50 cents per pound. In looking over the old patterns some years ago I found that many of them were finished and gated in a superior manner. Match plates, similar to those now used in machine moulding, were employed with good success and moulds were made rapidly. The flasks were made of cherry wood, and the workmanship on them was of the best. I am indebted to Horace Spaulding, of Easton, for much of my information. Mr. Spaulding, who is now 83 years of age, was a moulder in the East Boston Foundry, and is the only person now living who was concerned in the malleable iron works when first started. He relates that in the early days of the business Alex. Boyden used to have a little pump or syringe with which he used to squirt something into the air furnace stack, and also used to drop some kind of metal, probably zinc, into the molten iron, creating a smoke, all of which was to make a mystery of the process in the minds of the workmen.

One of the first malleable iron foundries in the central West was established in Cincinnati, O., previous to 1850, and possibly as early as 1845, by Miles Greenwood and Thomas R. Wood, under the firm name of M. Greenwood & Co. So far as can be learned, the works' practice was similar to that already described. Missouri surface ore pig was considered essential, and commanded an extra price on that account. The iron was melted in a cupola and later an air furnace was erected.

One salient feature of the malleable iron industry is the great amount of experimental work done in attempting to improve the process. From the time Seth Boyden began his elaborate series of experiments down to the present day, neither time nor money has been spared in putting into operation new methods. Most of these efforts have

been directed towards improving the annealing. Of course we always have had and probably always will have with us the man with the mysterious substance or "flux" which was to be added to the cupola charge or molten iron, and which was to produce malleable iron direct without any subsequent annealing. These metallurgical operations were usually accompanied by some financial operations on the foundryman's bank account, and this being accomplished, the man with the flux usually departed just before the heat was to be poured, to be seen no more.

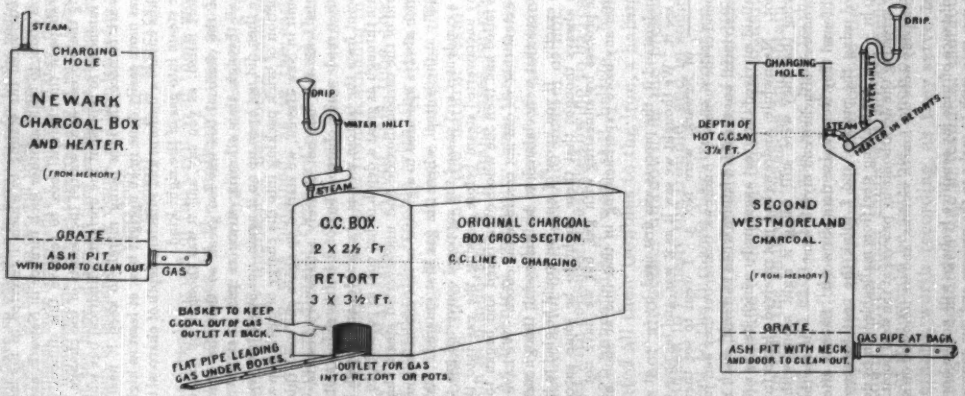
One attempt to introduce a new method of annealing, which was known as the Andrews process, was tried at a number of plants about 1875. The process consisted in passing water gas, which is composed of carbon dioxide, carbon monoxide and hydrogen, over the castings heated to redness. The water gas was generated by passing steam through red-hot charcoal in a retort contained in the large retort in which the annealing boxes were placed. Both the retort for generating the gas and that contained in the castings were heated from the same source. The plant consisted practically of a small water gas plant inside of a retort or annealing oven, suitable connections, of course, being provided for passing the gas over the castings and providing for its escape. The process could be made to work fairly well, but the mechanical difficulties of keeping the gas pipes, which were subjected to high temperatures, in good order were very great. Under the conditions which the Andrews process was installed, the proportion of carbon dioxide was probably too large, considerable steam was passing through the charcoal, and these two chemical reasons, with the mechanical difficulties mentioned above, caused the abandonment of the process. The reaction on which the decarbonizing process probably depended was the oxidizing action of carbon dioxide. This gas, by itself, is so active that both iron and graphite will be attacked; in other words, a scaly casting will result. Provided the carbon dioxide be diluted sufficiently, it still is able to oxidize the carbon, but will not attack the iron. At the time the process was introduced the idea was held that the hy-

drogen combined with the carbon to form some volatile hydrocarbon. These two elements do not unite directly, except at the temperature of the electric arc, when acetylene is formed.—"Richter's Organic Chem.," p. 153. In this case, as we are dealing with the ordinary temperature of the annealing retort, less than 1,000° C., it is highly improbable that this reaction could have taken place. Experiments with the Andrews process were carried out at the works of the Westmoreland Malleable Iron Company. Mr. F. M. Metcalf, treasurer of this company, has communicated to the writer his experience with this process. His account of the experiments, which extended over several years, is quite interesting, and I quote his letter, merely omitting some of the names.

WESTMORELAND, ONEIDA CO., N. Y., January 26, 1899.

Mr. Geo. C. Davis.

DEAR SIR:—Replying to your inquiry of the 25th, will say the water in the Andrews process of annealing was dripped into a funnel and ran through a pipe with a trap or bend in the pipe down through the top of the retort into an oval casting called the heater, which was at the top of the retort, just above the box of red-hot charcoal, which served as a water gas generator. Both received their heat in the same way through the brick in the retort. This was supposed to be sufficient to reduce the water to steam, and to some extent to superheat it, though Andrews did not favor superheating much. Steam passed from the heater into the top of the front of the charcoal box, which was as full of charcoal as practicable, and supposed to be all red hot, the same as the annealing boxes and contents when under heat. The steam having no other outlet, and the charcoal box being steam- and gas-tight, it passed down through the hot charcoal and out at the bottom back end of the charcoal box into a pipe leading under and by latch connections into the annealing boxes. In passing through the hot charcoal, it was theoretically converted into hydrogen and carbon monoxide. Over the opening in the charcoal box, where the gas made its exit, was an iron basket to protect the outlet from getting full of charcoal. There was very little pressure, as there was nothing but a six- or eight-inch column of water in the trap to prevent the steam backing out, and I think we had no check valves. I think I suggested higher pressure and hotter steam to Andrews, but he did not favor the steam being very dry, as I think he had tried superheated steam. I have given you rough sketches to show as well as I can with the short time at my disposal. The original charcoal box was rectangular, and say about five feet long. It was charged with charcoal through a luted door at the end and filled as full as possible, always fullest at the back, and after running a day or two was, of course, exhausted to a considerable extent. This reduced the depth of hot charcoal through which the steam was obliged to pass to so shallow a mass that it was thought that at that point the steam was not effectually converted, and



ANDREWS PROCESS OF ANNEALING CAST IRON.

Experiments made at the works of the Westmoreland Malleable Iron Company, Westmoreland, Oneida County, N. Y.

to that we attributed the scaling to which I referred in my last letter. As Andrews was about to build another such furnace in Newark, and intended to change the shape of the charcoal box to remove this difficulty, we discontinued using the process, and awaited the results of the change. One of the sketches is intended to represent the upright cylindrical box which was made for the Newark furnace, the idea being merely to keep it nearly full at all times, as was more easily done in an upright box, at least as high up as it got heat, and thus ensure a uniform and sufficient depth of charcoal to thoroughly convert the steam into gas of the right kind.

This effort failed, as you say, and it was thought by Andrews that the diameter of the charcoal box was too great, so that the charcoal did not get heated all through, thus allowing steam to pass that did not get converted. We then did not open up on it again, but about two years later, upon the introduction of brick packing into the charge of casting in a furnace that had been built in New Haven, we started up again and used this method for some months with fair but not entirely satisfactory results. To improve results we then made a new charcoal box of a bottle shape and heated it to as high a point from the bottom as was practicable, and hoped, by thus passing the steam through as great a depth of hot coal as possible, to be successful in getting rid of the carbon dioxide and unconverted steam that caused the scaling, which always appeared to a greater or less extent in some part of the charge, usually at the bottom, where the gas first entered. This failing, we introduced a condenser and passed the supposed converted gas through it to take out any unconverted steam before passing the gas into the annealing pots. This failed and then the whole oven failed and began to disintegrate to such an extent that we did not continue the effort. We have heard of gas annealing ovens that were claimed to be successful, though we could never place them exactly. If you know of any, we would be glad to hear of them, as we have always thought that there ought to be some successful way to improve the process by annealing with gas, but we have not "hankered" ourselves after any more experimenting in that line at such expense as we did the above.

As we understand it, the process was first used by ——— at ———, where we went to see it. We thought we saw it as it was, and became victim No. 2; ——— & ———, of Newark, were No. 3. I went to see their success on the third round of the furnace by Andrews' desire, but they had just completed what I was convinced was the third failure when I arrived, and I never learned whether Ballaid survived the great anger under which he was suffering on my arrival or not. Meanwhile, Andrews had just received a letter from the ——— people, saying that they were still using it right along with "charming results." Andrews, Minchen and myself went to ——— to see those charming results, and found they were worse than our worst. Shortly after that ——— discontinued using the process, and I think the next furnace was built in ——— shop in ———, for making steel from malleable iron by decarbonizing, and also by arresting the decarbonizing process at the steel point. The ——— & ——— Company were the fourth victims, and we followed on as the fifth, as above stated.

At this distance of time my sensitive feelings will not be hurt by any reference that you may wish to make to the process and our connection with it,

and we certainly have no objection to have you refer to the matter to such extent as you wish. We hope no one will think, however, that we have not learned to experiment more conservatively than we did then, though we are always open to improvements. I have answered you at much greater length than I intended, and hope, if you get tired reading the effusion, you will be compensated fairly by laughing at the victims, as I have learned to do.

Yours truly,

[Signed] F. M. METCALF, *Treas.*

Up to the breaking out of the Civil War there were few, if any, radical changes in the malleable iron production. With the growth of the country the business had gradually extended and foundry appliances had been enlarged and improved. The pig was obtained, as in the early days, from the Salisbury district, Orange County, and the Champlain district in New York State, and other furnaces scattered along the Atlantic seaboard from Katahdin in Maine to Stickney in Maryland. About this time there was experienced considerable trouble with the iron, owing to changes occurring in blast furnace practice. The hot blast was coming into use and the natural result was a higher silicon iron, unfitting it, in many cases, for malleable castings. As technical chemistry was then an unknown science, there was no reliable means of ascertaining in advance whether a lot of iron would answer or not. Some founders met with considerable losses owing to bad castings, which, though annealed soft, were still brittle. Naturally, they attributed all their troubles to the iron, a habit, by the way, that is not altogether unknown in the present day. Steps were taken to remedy the trouble, and in some cases men were sent to the furnaces disguised as workmen to find out whether hot blast was the sole cause of the difficulties or whether it was due to different ores. One manufacturer sent a man to visit the charcoal furnaces and obtain a sample of pig iron from each. This was sent back to the foundry, melted in a crucible and annealed. Such methods as these were expensive and required time before the result could be known. Even then there was no assurance that the next lot of iron would be suitable. Such experiences as these are, perhaps, worth recording, as they serve to illustrate the changed condition due to technical methods now

in use. At the present time, when a founder buys iron he orders it subject to certain chemical specifications, and he cares very little where it comes from or how it was made.

With the outbreak of the Rebellion, there arose an increased demand for iron for ordnance work, and the product and the output of many of the blast furnaces which had heretofore supplied the malleable iron foundries were absorbed by the U. S. Government. Fortunately, the Lake Superior region had been developed, and as pig iron from this district was found to be admirably suited for malleable work, its use rapidly extended. The first Lake Superior iron was brought into this locality about 1862. The source of supply of charcoal malleable is still from the lake region.

The malleable iron industry has undoubtedly been developed to a greater extent in the United States than in any other country. Mr. R. A. Hatfield, *Journal B. I. and S. I.*, vol. I, 1897, page 180, says, in his discussion of a paper by Mr. G. P. Royston, on malleable iron: "The author's paper was especially valuable, too, as calling attention to a line of work to which they in the United Kingdom had not paid sufficient attention; that was the production of malleable iron castings, for in America that industry was carried on on a very large scale. Its production had been so thoroughly specialized that he questioned whether they could touch either the price or quality which were being obtained in the United States. A large user in Sheffield had told him that he had to send for execution in America very considerable requirements, the price of castings being exceedingly low, the quality excellent, and time of delivery short, as compared with English makers." There are at present in this country about ninety malleable iron foundries, varying in capacity from one to eighty tons per day. Nearly all of them are located north of the Ohio and east of the Mississippi. They are quite evenly distributed over that region, though of the New England States, Maine and Vermont have none. There is in the Southern States only one malleable iron foundry, and in the entire West, from the Mississippi to the Pacific Slope, not one exists.

By far the heaviest tonnage goes into car castings and

farm implements. Since malleable castings have sold so low, they have, to a considerable extent, replaced gray iron castings for many purposes, especially in car building. Broadly speaking, the founders in the central West are mainly devoted to the heavier castings, while the Eastern foundries manufacture a very large variety of small articles, such as carriage and harness hardware, pipe fittings, bicycle fittings, ship hardware, parts of textile machinery, typewriters, gun locks, pistol frames and, to use a somewhat hackneyed phrase, "other articles too numerous to mention."

There are at present at least five coke blast furnaces that produce largely malleable pig. Two of these are in New York State, and one each in Pennsylvania, Illinois and Tennessee, so the source of supply is not centralized. The coke malleable differs from the charcoal in being a trifle higher in sulphur and considerably higher in manganese. The difference in sulphur is not great enough to be of any importance where the iron is melted in an air furnace, while the high manganese renders it desirable for mixing with charcoal irons, which are, as a rule, too low in this element. Coke malleable has now been in use for about fifteen years, and its consumption is undoubtedly increasing. It was thought at one time that some of the numerous steel casting processes would replace malleable iron. By steel I mean the product of the open hearth or modified Bessemer, and not any of the numerous semi-steels. In the heavier classes of work this has to some extent proven true, but, as a rule, the two processes are developing along different lines. The difficulties of preparing small moulds to withstand the high temperature of steel, and the more costly plant necessary for its production will probably prevent its use for small or intricate castings.

In closing, the writer wishes to acknowledge his indebtedness to Mr. O. S. Boyden, and the late W. G. Morris, of Newark, N. J.; Milton H. Robbins, of Lakeville, Conn.; George C. Belcher and Horace Spaulding, of Easton, Mass.; James L. Haven, of Cincinnati, O.; John Dessalet, of Philadelphia; F. M. Metcalf, of Westmoreland, N. Y., and Thos. Devlin, of Philadelphia, at whose suggestion this paper was undertaken.

Mechanical and Engineering Section.

Stated Meeting, held Thursday, March 9, 1899.

MECHANICAL APPLICATIONS OF COMPRESSED AIR.

(Abstract of remarks by Mr. W. L. SAUNDERS, M. Am. Soc. C. E., Member of the Institute, in opening the discussion.)

[*Concluded from p. 134.*]

At the same time the car is being charged with air, another nozzle is introduced to the heater connection, and live steam from the boilers is admitted, until the temperature registered is about 300° F.

The air storage reservoirs on these cars have a capacity of 51 cubic feet, sufficient to run the car eighteen to twenty miles continuously, or from fourteen to seventeen miles making the stops incident to ordinary street railway service. A larger capacity could readily be installed on the car, giving it ample power to run twenty miles with a reserve. The reservoirs consist of seamless steel flasks capable of standing a pressure of double that used without reaching the elastic limit of the metal and with no possibility of leakage. They are 9 inches in diameter and of varying lengths adapted to their location under the seats and the car floor. Between the flasks and the motor is placed a small tank containing 6 cubic feet of water, which is heated as before described. The tank is jacketed with non-conducting material preventing external radiation. This provides not only against loss of heat, but also against any perceptible rise in the surrounding atmosphere, so that no discomfort can arise from it.

Numerous trials have proved that the application of heat as employed in this system enables the cars to run nearly double the distance that cold air will carry them.

In operation, the compressed air, after passing through a reducing valve and being lowered to 150 pounds to the

square inch (the working pressure), circulates freely through the hot water, and a mixture of heated air and vaporized water passes to the motors, working expansively, the terminal pressure being so low as to cause no sound in exhausting the air.

The motor mechanism consists of two simple link-motion, reciprocating engines having cylinders 7 inches in diameter and 14-inch stroke, with valves cutting off at from 1-10 to 1-6, and applying the power by connecting and parallel rods

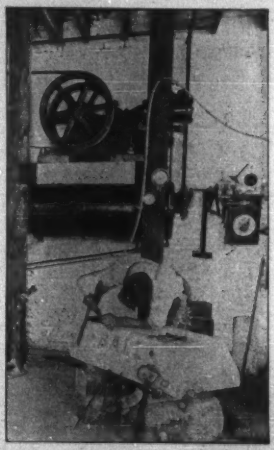


FIG. 26.—Lettering with the pneumatic tool.

direct to the crank pins of the drive wheels, which are four in number, 26 inches in diameter, running on a wheel base of 7½ feet. Upon this four-wheeled truck rests the entire weight of the car and mechanism, evenly distributed upon elliptic springs, enabling the car to pass much more smoothly over bad track and crossings than an electric car (on which the motors are a dead weight upon the axles), besides being a great saving in wear on the rails at the joints, and on the rolling stock.

The mechanical features of the motors are substantially

identical with those of a steam locomotive, minus fire-box and boiler, which, in point of perfection in mechanism as a moving power, is too well known to need any comments.

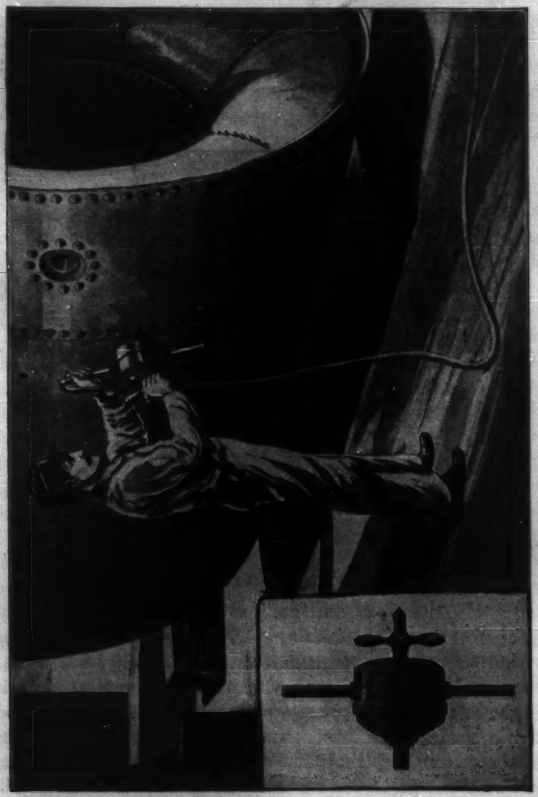


FIG. 27.—The piston air drill, for tapping, drilling, reaming, and rolling flues.

The manipulation of the car is simplicity itself, requiring no special skill or training to handle with perfect facility,

and capable of being moved in either direction as little as 2 inches.

It is perfectly noiseless, odorless, and entirely free from

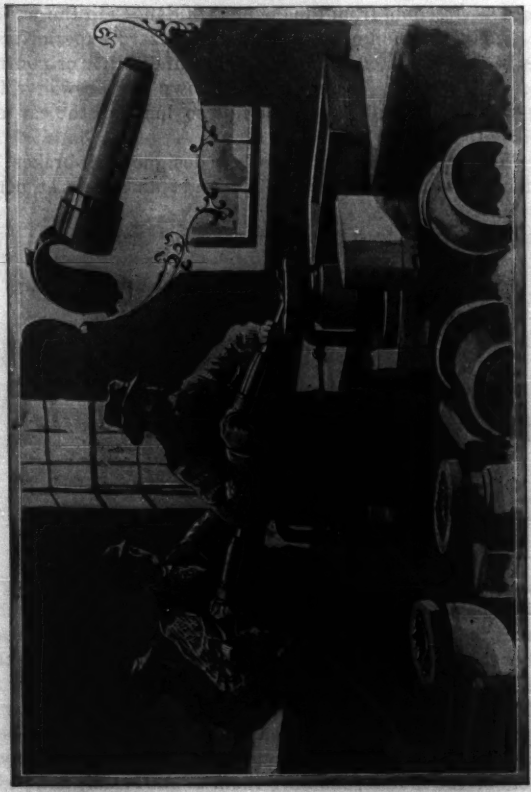


FIG. 28.—Chipping iron and steel castings.

any other offensive feature, sending neither smoke nor steam into the air. It responds to the starting and stopping

devices with remarkable promptness, operating without any jerks or jars.

This feature of easy and perfect control seems to me to be the most vital point in its relation to the public; as in other respects (freedom from the element of danger to the public as a manifestation of power), its non-hazard superiority is easily demonstrated. The ease and infallibility of control excels that of any other system known to the writer for street railways, and can never fail so long as the car has ability to move.

The car is fitted with specially designed air-brakes of sufficient power, with the high-pressure air always at com-

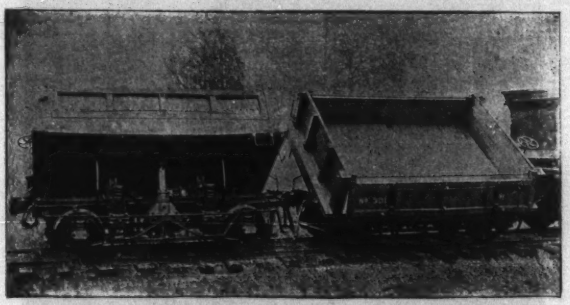


FIG. 29.—Pneumatic car dump.

mand, to set the wheels instantly if desired, by a single wrist movement of the motorman. Upon releasing the brakes there is an entire absence of noise of any kind from either the mechanism or escaping air, which is so noticeable and annoying with air-brakes generally.

The same lever that releases the brakes operates, by a slight advancing movement on the quadrant, to open a by-pass admission of the compressed air, directly into the cylinders of the motors, enabling them to start easily and positively, whatever the position of the cut-off valves may be, and preventing any possibility of being stopped on "dead centers," after which the throttle is opened. This ability to

start so promptly and surely under all conditions is a feature possessed by no other reciprocating motor, and the inability to overcome this difficulty has been one of the principal causes of failure in kindred types of motors heretofore exploited. The application of the principle of a by-pass admission of air into the cylinder seems to be confined exclusively to the motors of the General Compressed Air Company, and is of the greatest importance, materially affecting the economic operation of the motors, aside from assuring their infallibility in starting.

FIG. 30.—Wood boring.

The entire system embodying the mechanism and method of developing and applying the power, for the purposes under consideration, consists of simple, practical devices, operating on the most approved principles, from which all offensive and uneconomic features have been eliminated and better fulfilling the requirements of an ideal means of street car propulsion than any other within the writer's knowledge.

Following are illustrations given with titles only of other important applications of compressed air, detailed descriptions of which may be obtained from the files of a little paper which I publish called *Compressed Air*.

Compressed air is also usefully applied for locomotive

FIG. 31.—Pneumatic motor on apparatus for breaking scrap.

bell ringing, tinware presses, elevator door openers, the artist's air brush, fire-alarm whistle, shaking grates, steam hammers, hydro-pneumatic cranes, hydraulic pressure relief, wood-pulp machines in paper mills, ice making, lard refining, dentist tools, medical spray apparatus, pneumatic tires,

pneumatic beds and cushions, mixing and cooling nitro-glycerine, pile driving, pneumatic ejector, pneumatic presses, the straightening press, pipe bending apparatus, spraying colors in pottery work, whitewashing, raising metal to cupolas in foundries, removing scale from steel or iron

FIG. 32.—Caulking a pipe line.

plates, flue cleaning, steering ships, boring, drilling and finishing stone, elevating sand and water in stone sawing, tapping iron furnaces, testing brakes, pneumatic guns for throwing dynamite, raising pressure of natural gas, oil well

pumping, locomotive service in mines and docks, freezing quicksand, belt shifting, derricks, central pneumatic system of lubrication, liquid air, ditching machinery, combined with oil or gas for engine power driving, glass blowing, dredging, flue welding, grouting apparatus, horse collars, hose press, refrigerating and cooling, moulding machines in foundries,

FIG. 33.—Sheep shearing in Australia.

purifying water, blacksmith forges, creating forced draughts in boilers and furnaces, copying press, disappearing gun carriage, ringing chime bells, stone-channelling machines, coal cutters, pneumatic switch and signal service, car signal on train, satin finish on metal work, kindling fires, grain elevators, dampening in laundry work, diving armor, sewage

disposal, driving motors or air engines of various kinds, clipping horses, coal or culm conveyors, lighting, agitating syrup in sugar refineries, beating eggs, raising beer, automatic fire-extinguisher service, propelling torpedoes and torpedo boats, sand-papering, aërating fuel, refining asphalt, excavating cesspools, finishing silk ribbon, for dry dock and canal lock service, agitating acids, ventilating in mines, cotton compresses, vulcanizing wood, temperature regulators, raising sunken vessels, driving printing presses and other individual tools, operating clocks, etc.

CHEMICAL SECTION.

Stated Meeting, held February 18, 1899.

THE LABORATORY PRODUCTION OF ASPHALTS FROM ANIMAL AND VEGETABLE MATERIALS.*

BY WM. C. DAY.

By carrying out operations of distillation at the ordinary atmospheric pressure upon animal and vegetable matter, both separately and mixed, I have succeeded during the past year in producing three different materials, all of which present in different degrees the properties characteristic of asphalts. Two of these materials quite closely resemble asphalts occurring in nature, namely, gilsonite and elaterite, as found in Utah.

Postponing for the present a consideration of the reasons which led to these experiments, I will first give a description of the work done and a statement of the results obtained since the publication last summer of a preliminary paper† on the same subject.

The first experiment was to distil from an iron retort a mixture of fresh fish (herring from the Delaware) and fat pine wood, partly in the form of sawdust and partly in

* Published by permission of the U. S. Geological Survey.

† "Proc. Amer. Philos. Soc.," **37**, 171.

sticks. The retort was connected with a short glass tube by means of a joint of plaster-of-paris and asbestos; this tube was connected at the other end by a similar joint with a small iron gas pipe four feet long, placed upon a combustion furnace, by which it could be maintained at a red heat. The retort was heated by gas furnaces and the distillation was carried to complete carbonization of the organic matter. An ordinary Liebig's condenser served to condense the mixed oil and water as it issued from the red-hot gas pipe. The distillation product consisted of water of a yellowish-red color, and a dark, nearly black, mobile oil, which for the greater part floated upon the water, although toward the close of the distillation a little oil would usually sink through the water.

Twelve operations of distillation consumed 9,882 grams of wood and 8,170 grams of fish, and yielded 3,010 cubic centimeters oil, of specific gravity 0·9837, and 8,240 cubic centimeters water. The average distillation shows, therefore, the figures 823·5 grams wood, 680·8 grams fish, 250·8 cubic centimeters oil and 686·7 cubic centimeters water; these average figures were approximated in each single distillation.

The oil was separated from the water and then dried by standing over chloride of calcium. A combustion of this oil, using copper oxide and lead chromate, gave the following results:

0·3104 gram oil gave 0·9593 gram CO_2 and 0·2794 gram H_2O, or

	Per Cent.
Carbon	84·28
Hydrogen	10·00

The dried oil was then subjected to distillation by itself in a hard glass retort provided with thermometer. A few drops of oil, accompanied by a little moisture, came over at 80° C.; the temperature rose rapidly to 120°, at which point distillation proceeded rapidly, giving a distillate lemon yellow in color and slightly turbid from moisture. The receiver was changed at 180°, when the distillate appeared darker in color but free from moisture. The receiver

was changed at 245°, 315° and 340°, at which last point the thermometer was removed; after this the distillation was conducted to about 425° as nearly as could be judged by the rate at which the temperature had been rising. At 315° a greenish fluorescence appeared. When the boiling was stopped the contents of the retort consisted of a mobile, homogeneous, black liquid containing no solid particles of any kind. When the retort cooled this oil solidified to a black, shining mass, showing conchoidal fracture, brittle and pulverizing to a brownish-colored powder slightly darker than the powder of Utah gilsonite, which, in appearance, it closely resembled; in fact, it was only by the rounded surface of the artificial product that the two could be distinguished by inspection. A number of distillations were made with essentially the same experience as just described, except that the material obtained the first time was slightly sticky to the touch and entirely soluble in carbon bisulphide, while the samples obtained subsequently were not at all sticky, and were not entirely soluble in the bisulphide.

Subjected to combustion, the sample resulting from the first distillation gave the following result: 0·2211 gram substance gave 0·7100 gram CO_2 and 0·1540 gram H_2O, or

	Per Cent.
Carbon	87·57
Hydrogen	7·74

Two combustions of the artificial gilsonite finally made in quantity gave the following results:

I. 0·2529 gram substance gave 0·8031 gram CO_2 and 0·1599 gram H_2O.

II. 0·3015 gram substance gave 0·9564 gram CO_2 and 0·1938 gram H_2O.

	I. Per Cent.	II. Per Cent.
Carbon	86·61	86·51
Hydrogen	7·02	7·19

Two nitrogen determinations by Kejhldahl's method, using in the first case 1·1990 grams substance, and in the second 0·9824, gave nitrogen 1·95 and 1·86 per cent., respectively.

Two determinations of sulphur by Peckham's method* resulted as follows:

I. 2·0218 grams substance gave 0·0136 gram $BaSO_4$.

II. 1·9988 grams substance gave 0·0114 gram $BaSO_4$.

	I. Per Cent.	II. Per Cent.
S=	0·092	0·078

According to the figures obtained, the composition of the artificial gilsonite appears to be as follows: For the sake of comparison, the figures for natural Utah gilsonite are also given here, as well as elsewhere.

	Artificial. Per Cent.	Natural. Per Cent.
Carbon	86·56	85·83
Hydrogen	7·06	10·59
Nitrogen	1·91	2·59
Sulphur	0·08	0·26
Oxygen (by dif.)	4·39	0·63
		Ash, 0·10
	100·00	100·00

While the differences in composition between these two materials are not great, still they can by no means be regarded as insignificant, particularly as regards those in the cases of hydrogen and oxygen. It is true, however, that much greater differences between two natural asphalts taken from sources in the same neighborhood have been found.

Determinations of solubility in the following solvents were made: Carbon bisulphide, turpentine, ether, gasoline and absolute alcohol. The method employed was to treat a weighed portion of the substance with the solvent until no further action took place, and then weigh the undissolved residue on a tared filter.

CARBON BISULPHIDE.

I.

Weight of substance taken	0·5505
" " undissolved residue	0·1060
" " dissolved substance	0·4445

Per cent. soluble in CS_2 = 80·74.

Journal Soc. Chem. Ind., **16**, No. 12, 1897.

II.

Weight of substance taken	0·6970
" " undissolved residue	0·1293
" " dissolved substance	0·5677

Per cent. soluble in CS_2 = 81·44.

TURPENTINE.

Weight of substance taken	0·9041
" " undissolved residue	0·4568
" " dissolved substance	0·4473

Per cent. soluble in turpentine = 49·47.

ETHER.

Weight of substance taken	0·5776
" " undissolved residue	0·1904
" " substance dissolved	0·3872

Per cent. soluble in ether = 67·03.

GASOLINE.

Weight of substance taken	0·5339
" " undissolved residue	0·2845
" " substance dissolved	0·2494

Per cent. soluble in gasoline = 46·71.

ABSOLUTE ALCOHOL.

Weight of substance taken	0·5547
" " undissolved residue	0·2862
" " substance dissolved	0·2685

Per cent. soluble in alcohol = 48·40.

All the solutions obtained were characterized by a more or less marked greenish fluorescence, which is also true of the natural gilsonite.

ACTION OF SOLVENTS.

Solvent.	Utah Gilsonite.		Artificial Gilsonite.
Carbon Bisulphide	99·50	first product,	100·00
		second "	81·44
Turpentine	97·34		49·47
Ether	73·08		67·03
Gasoline	63·08		46·71
Alcohol	34·81		48·40

While the above table shows in some cases quite notable differences in solubility, every one of the solvents exercises

in each case a pronounced effect, all figures being above 30 per cent., and generally nearly 50 per cent. or more.

The action of concentrated nitric acid upon the natural and the artificial material is peculiar, and of exactly the same character. This action consists in completely dissolving the material with copious evolution of brown fumes and the production of a dark-red solution, which, upon diluting with water, yields a flocculent precipitate much resembling freshly precipitated ferric hydroxide.

In the course of an investigation of Utah gilsonite,* carried out some years since, I separated from the oils distilled from the mineral certain basic compounds suggestive in odor of the pyridine or quinoline series. These bodies were obtained by the extractive action of dilute sulphuric acid upon the oils. From such solution they are thrown down by alkalies as flocculent precipitates.

The same kind of substances were obtained from the oil which, by distillation, yielded the artificial gilsonite. The method of treatment adopted to extract these basic substances was to shake the oil with dilute sulphuric acid and then pass steam into the mixture contained in a large flask until oil no longer distilled off with steam. On neutralizing the residual acid with caustic soda solution, a precipitate looking and smelling like that from gilsonite oil was obtained. The precipitate was alternately redissolved in sulphuric acid and reprecipitated by alkali a number of times, and then, after washing with water, was left on a filter to dry. On drying, however, the material largely disappeared, thus showing its volatility, which the solid appearance when freshly precipitated had failed to suggest. It is evident, however, that the presence of these basic compounds affords another element of similarity between the natural and the artificial product, and also between these bodies and California petroleum.

DISTILLATION OF FISH ALONE.

The interesting character of the product obtained by distilling a mixture of fish and wood, and the similarity

* *Journal Franklin Institute*, **160**, 221.

between this and Utah gilsonite, suggested the advisability of carrying out the same kind of experiments with fish alone and also with wood alone. Accordingly, a number of charges of the same kind of fish were distilled, using the same apparatus as was employed for the mixture of wood and fish.

In all 4,585 grams of fish were distilled, yielding 700 cubic centimeters of oil and 2,830 cubic centimeters water. The distillate consisted of a yellow emulsion difficult to break up; the distillate from the fish and wood mixed gave no emulsion at all, but presented a well-defined line of separation between the oil and water. The emulsion was separated into oil and water by heating upon the water-bath, the oil being eventually brought to the surface of the water. Much ammonia was produced during the distillation.

An attempt was made to dry the oil by allowing it to stand over chloride of calcium for a number of days, but it could not be perfectly dried in this way. Success in drying was finally attained only by aspirating a current of dry air through the oil while it was heated upon the water-bath.

On attempting to distil the fish oil from a retort, as was done with the oil from the mixture of fish and wood, such vigorous and explosive "bumping" was encountered as to carry the contents of the retort over mechanically so that it was found impossible to distil it in this way. The appearance of moisture during this attempt to distil an oil which had been thoroughly dried made it evident that the water was formed during the distillation. The oil was transferred from the retort to an iron crucible and heated cautiously until the stage of water formation was passed, and then heated more strongly. After heating for a time the contents of the crucible were allowed to cool, when a very sticky, thick semi-liquid mass remained. It looked and smelled more like a maltha from Montana that I had examined a few years since than anything else I could compare it to. The material was again heated in the crucible, boiling it freely; on cooling again a solid was obtained, black in color and elastic, so that if bent nearly double it would fly back to its original shape like a thick piece of India rub-

ber. It could be easily cut, but not pulverized, although if struck a blow with a hammer it would break with conchoidal fracture.

Determinations of carbon, hydrogen and nitrogen were made with the following results:

I. 0·2366 gram substance gave 0·6638 gram CO_2 and 0·1933 gram H_2O.

II. 0·2333 gram substance gave 0·6618 gram CO_2 and 0·1916 gram H_2O.

III. 0·2233 gram substance gave by Kejhldahl's method ammonia corresponding to 4·19 per cent. of nitrogen.

IV. 0·8896 gram substance gave ammonia corresponding to 4·27 per cent. nitrogen.

V. 2·0402 grams substance gave 0·0287 gram $BaSO_4$.

VI. 1·9954 grams substance gave 0·0276 gram $BaSO_4$.

	I.	II.	III.	IV.	V.	VI.
Carbon	76·51	77·36	—	—	—	—
Hydrogen	9·08	9·12	—	—	—	—
Nitrogen	—	—	4·19	4·27	—	—
Sulphur	—	—	—	—	00·19	00·19

This material, if cooled down, became harder and less susceptible of bending; the same kind of change seemed to result also as the material became older, as after some months it became harder and more brittle.

The following results of analysis were obtained upon a sample of elaterite from Utah. This material in lump form was hard and not at all capable of being bent; it was, however, quite flexible when sawed into thin slabs. The percentages of carbon and hydrogen found are not far removed from those of the asphalt from fish alone.

I. 0·2993 gram substance gave 0·8024 gram CO_2 and 0·2550 gram H_2O.

II. 0·1995 gram substance gave 0·5404 gram CO_2 and 0·1698 gram H_2O.

	I.	II.
Carbon	73·11	73·88
Hydrogen	9·46	9·45

Further investigation of this material is now being carried out. According to Dana's "Mineralogy," p. 734, elaterite analyzed by Johnston contains 84 to 86 per cent. car-

bon, and 12·3 to 13·2 per cent. hydrogen. I am unable to give the authority for calling the Utah material elaterite, but in composition it evidently resembles much more nearly the material obtained from fish than it does the elaterite described by Dana. The much lower percentage of carbon than is contained in gilsonite is noteworthy.

Treatment of oil obtained from fish alone with dilute sulphuric acid gave a solution of basic nitrogen compounds which could be precipitated by alkalies, just as in the case of oil from natural or artificial gilsonite. The odor of these basic substances was of the same character, whatever the source.

The following determinations of the solubility of the asphalt from fish alone were made:

CARBON BISULPHIDE.

Weight of substance used	0·2999
" " " undissolved	0·0954
" " " dissolved	0·2045

Per cent. soluble in CS_2 = 68·19.

TURPENTINE.

Weight of substance used	0·3163
" " " undissolved	0·1665
" " " dissolved	0·1498

Per cent. soluble in turpentine = 47·36.

ETHER.

Weight of substance used	0·2662
" " " undissolved	0·1087
" " " dissolved	0·1575

Per cent. soluble in ether = 59·17.

GASOLINE.

Weight of substance used	0·3733
" " " undissolved	0·2419
" " " dissolved	0·1314

Per cent. soluble in gasoline = 35·19.

ABSOLUTE ALCOHOL.

Weight of substance used	0·4239
" " " undissolved	0·2074
" " " dissolved	0·2165

Per cent. soluble in alcohol = 51·07.

DISTILLATION OF WOOD ALONE.

The same kind of rich and heavy pine as was used in mixture with fish was subjected to distillation by itself. In all 4,588 grams were used, yielding 1,150 cubic centimeters of oil and 890 cubic centimeters water.

It is interesting to note here the much larger proportion of oil obtained than resulted from the distillation of fish alone. The distillation was accompanied by the production of a thick, white smoke, which could not be condensed. The distillate was strongly acid. The oil, after drying, showed a specific gravity of 0·992. It was subjected to distillation by itself, collecting the same fractions as were taken in the case of the distillation of oil from wood and fish. The first fraction, 90° — 145°, was light-yellow in color, and slightly turbid from moisture; the second, 145° — 180°, was darker yellow; the third, 180° — 245°, was greenish-black; the last one showed green fluorescence. After distilling off somewhat more than half the oil, the black, but perfectly mobile liquid, was allowed to cool, when it solidified to a black shining mass, very brittle and showing conchoidal fracture. While the general color was black, inspection of a thin edge along a line of fracture showed a purple color, such as could not be seen with the material from wood and fish. The specific gravity was found to be 1·0825.

When pulverized, the powder, in the course of several days, would cement together and re-form a hard, rigid mass.

Determinations of carbon, hydrogen and nitrogen gave the following results:

0·2078 gram substance gave 0·6568 gram CO_2 and 0·1549 gram H_2O.

0·9362 gram substance gave ammonia corresponding to 0·26 per cent. nitrogen.

0·8884 gram substance gave ammonia corresponding to 0·33 per cent. nitrogen.

Determinations of sulphur gave only traces.

	Carbon.	Hydrogen.	Nitrogen.
I.	86·20	8·28	—
II.	—	—	0·26
III.	—	—	0·33

The following determinations of solubility were made:

CARBON BISULPHIDE.

I.

Weight of substance used	0·3604
" " " undissolved	0·0050
" " " dissolved	0·3554

Per cent. soluble in CS_2 = 98·61.

II.

Weight of substance used	0·3868
" " " undissolved	0·0003
" " " dissolved	0·3865

Per cent. soluble in CS_2 = 99·92.

TURPENTINE.

I.

Weight of substance used	0·4498
" " " undissolved	0·0155
" " " dissolved	0·4343

Per cent. soluble in turpentine = 96·55.

II.

Weight of substance used	0·4218
" " " undissolved	0·0167
" " " dissolved	0·4051

Per cent. soluble in turpentine = 96·04.

ETHER.

I.

Weight of substance used	0·3589
" " " undissolved	0·0153
" " " dissolved	0·3436

Per cent. soluble in ether = 95·45.

II.

Weight of substance used	0·4084
" " " undissolved	0·0130
" " " dissolved	0·3954

Per cent. soluble in ether = 96·81.

GASOLINE.

I.

Weight of substance used	0·5342
" " " undissolved	0·0441
" " " dissolved	0·4901

Per cent. soluble in gasoline = 91·74.

II.

Weight of substance used	0·3582
" " " undissolved	0·0412
" " " dissolved	0·3170

Per cent. soluble in gasoline = 88·49.

ALCOHOL.

Weight of substance used	0·5548
" " " undissolved	0·2130
" " " dissolved	0·3418

Per cent. soluble in alcohol = 61·60.

High solubility is characteristic of this material in all cases.

A quantity of the oil from wood alone was treated with dilute sulphuric acid for the purpose of testing for basic oils. No trace of these oils could be precipitated, however, by neutralizing the acid with sodium hydroxide.

In connection with the present investigation a complete analysis of Utah gilsonite has been made with results that are somewhat lower in carbon and in sulphur than those obtained and published a few years since.* Instead of using finely-powdered lead chromate together with copper oxide, as was the case in the first analysis, a large quantity of coarse granules of lead chromate were employed with results that showed better agreement.

In this connection it should be remarked that the use of copper oxide in hydrocarbon combustions has not infrequently given trouble in the form of irregularities in the figures for carbon. Professor Peckham, in a recent conversation, called my attention to a remark made to him by Warren to the effect that copper forms carbides which are oxidized with difficulty, and hence, according as these are formed or oxidized in succeeding combustions, the figures for carbon will vary. This point is now being investigated. Certain it is, however, that asphalts are troublesome substances in elementary analysis. This statement is thoroughly borne out by a study of the literature of these bodies.

* *Journal Franklin Institute*, **160**, 221.

The following are the results of analysis of Utah gilsonite:

I. 0·2738 gram substance gave 0·2603 gram H_2O and 0·8631 gram CO_2.

II. 0·2017 gram substance gave 0·1930 gram H_2O and 0·6336 gram CO_2.

III. 1·0347 grams substance gave ammonia by Kejhldahl's method corresponding to 2·65 per cent. nitrogen.

IV. 0·9363 gram substance gave ammonia corresponding to 2·53 per cent. nitrogen.

V. 2·1651 grams substance gave 0·0390 gram $BaSO_4$.

VI. 2·0017 grams substance gave 0·0388 gram $BaSO_4$.

	Carbon.	Hydrogen.	Nitrogen.	Sulphur.
I.	85·98	10·56	—	—
II.	85·67	10·62	—	—
III.	—	—	2·65	—
IV.	—	—	2·53	—
V.	—	—	—	00·25
VI.	—	—	—	00·27

Taking the averages of these results, the percentage composition appears to be:

Carbon	85·83
Hydrogen	10·59
Nitrogen	2·59
Sulphur	00·26
Oxygen (by dif.)	·63
Ash*	·10
	100·00

*Quoted from paper on gilsonite, *Journal Franklin Institute*, 160, 221.

TABLE GIVING ANALYTICAL RESULTS.

Name of Substance.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.
Oil from fish and wood	84·28	10·00	undtm.	undtm.	undtm.	none
Artificial gilsonite from first preparation	87·57	7·74	"	"	"	"
Artificial gilsonite made finally	86·56	7·06	1·91	0·08	4·39	"
Utah gilsonite	85·83	10·59	2·59	0·26	0·63	0·10
Asphalt from fish alone	76·93	9·10	4·18	0·19	9·60	none
Utah elaterite	73·11	9·45	1·90	3·17	12·37	trace
Alphalt from wood alone	86·20	8·28	0·29	trace	5·23	none
Utah nigrite	83·33	8·69	undtm.	0·42	undtm.	0·12

	Fixed Carbon.	Volatile Matter.	Ash.
Utah nigrite	36·33	63·55	0·12

The specific gravities of various substances, determined in the course of the present investigation, are given in the following table:

SPECIFIC GRAVITIES.

Oil obtained from primary distillation of fish and wood, temperature 26° C.	0·9837
First fraction of above oil, 80–145° C. when distilled by itself, temperature 25·8° C.	0·842
Last fraction in same distillation, 340° C., temperature 25·9° C.,	1·002
Utah gilsonite, temperature 26° C.	1·0354
Artificial gilsonite, temperature 26° C.	1·1713
Asphalt obtained from wood alone, temperature 26° C.	1·0825
Alphalt obtained from fish alone, temperature 26° C.	1·0590
Oil from wood and fish, volatile with steam, temperature 26° C.,	0·8940
Oil obtained in primary distillation of wood, temperature 26·4° C.	0·9920

TABLE OF SOLUBILITIES IN VARIOUS SOLVENTS.

Name of substance.	Carbon Bisulphide, all.*	Turpentine.	Ether.	Gasoline.	Absolute Alcohol.
Artificial gilsonite	81·09	49·47	67·03	46·71	48·40
Utah gilsonite	99·50	97·34	73·08	63·08	34·81
Asphalt from fish alone	68.19	47·36	59·17	35·19	51·07
Asphalt from wood alone	99·26	96·29	96·13	90·12	61·60

* This determination involved no weighings, as when the solution was filtered nothing insoluble remained behind on the filter.

The foregoing experiments suggested themselves as the result of a number of years of experimental work upon asphalts from a number of natural sources in the Western part of the United States and a study of the literature of natural hydrocarbons, solid, liquid and gaseous, and the synthetical experiments which have been carried out by Warren, Engler and Sadtler. From the chemical-geological standpoint the writings of Peckham have been very suggestive, advocating, as they have done, the idea that bitumens are distillates together with water of organic matter, which has accumulated in strata of all ages in the earth.

Utah gilsonite is the natural material to which the writer has given most experimental study. This mineral contains very little oxygen and sulphur, almost no ash, but a notable quantity of nitrogen, which shows itself in distillation pro-

ducts in the form of basic substances similar in a general way to the pyridine and quinoline series, and of the same character as the basic substances obtained by Peckham and Salathé from California petroleum, and freely commented upon by Peckham in a number of papers by him.

These nitrogen compounds suggest animal origin of the bodies containing them. It seemed, however, to the writer that a material having exclusively animal origin would be likely to contain a larger proportion of oxygen than is contained in such material as natural gilsonite, and that in laboratory experiments to reproduce asphalts low in oxygen, vegetable material should be present at the same time, and that opportunity should be afforded for the oxygen containing distillates from oils and animal substances to react at a fairly high temperature with the abundant gaseous hydrocarbons produced by distilling wood or in general vegetable material. The result of such reaction between bodies of the nature just described would be to eliminate oxygen from the oily distillate by causing it to form water and carbon dioxide with the hydrogen and carbon of gaseous hydrocarbons. This idea was strengthened by the fact that in his experiments to produce petroleum-like substances and paraffine from linseed oil Sadtler* noticed the odor of acrolein and referred to it as follows: "At first the odor of acrolein was very pronounced and powerful, showing that the glycerine of the glycerides composing the oil was being decomposed; later the odor was more that of a cracked petroleum oil, showing that the linoleic and other aids of the oil were undergoing decomposition." On another page the same writer says: "Of course the fractions must be obtained on a sufficiently large scale to admit of thorough purifying before the character of the hydrocarbons can be studied. At present they contain impurities, such as aldehyde-like and possibly ketone products. They reduce ammoniacal silver solutions and indicate thus the presence of these impurities."

The following facts, based upon a consideration of the

* "Proc. Amer. Philos. Soc.," **36**, 93.

character of the distillates obtained from the mixed animal and vegetable matter, the fish alone and the wood alone, tend to show the correctness of the writer's position in an attempt to produce an asphalt low in oxygen. The table of ultimate analyses given below shows that there is less than half as much oxygen in the asphalt from wood and fish mixed as in that from fish alone.

ULTIMATE ANALYSES.

	Ash.	Carbon.	Hydrogen.	Sulphur.	Nitrogen.	Oxygen.
Utah gilsonite . . .	0·10	85·83	10·59	0·26	2·59	0·63
Utah elaterite . . .	—	73·49	9·46	undtm.	undtm.	17·05
Artificial gilsonite from wood and fish . .	—	86·56	7·06	0·08	1·91	4·39
Asphalt from wood .	—	86·20	8·28	trace	0·29	5·23
Asphalt from fish . .	—	76·93	9·10	0·19	4·23	9·55

The following table, giving the yields of water and oil in the various distillations, is also of interest, as showing the effect of water forming reactions between hydrocarbons and oxygen compounds, which, doubtless, took place in the hot tube through which the vapors were passed before condensation.

Material Used, Grams.		Oil Produced, Cubic Centimeters.	Water Produced, Cubic Centimeters.
Wood.	Fish.		
9,882	8,170	3,010	8,240
—	4,585	700	2,830
4,588	—	1,150	890

If the wood and fish, when distilled together, had yielded oil and water in the same proportion as when each was distilled by itself, then there should have been a yield of 3,724 cubic centimeters of oil from the mixture, instead of the 3,010 cubic centimeters actually produced, and, instead of 8,240 cubic centimeters of water, there should have been only 7,321 cubic centimeters.

The question of the origin of asphalts is one that cannot be intelligently discussed apart from that of the origin of petroleum, or, more broadly still, apart from the origin of the bitumens in general, which include natural hydrocarbons in all states of matter, solid, liquid and gaseous. Of these three states, liquid petroleum has, for a variety of

obvious reasons, received the most attention scientifically and technologically.

The connection quite generally believed at present to exist between petroleum and the asphalts is expressed in Dana's "Mineralogy," p. 751, as follows: "The more solid kinds graduate into the pit asphalts, or mineral tar, and through these there is a gradation to petroleum. The fluid kinds change into the solid by the loss of a vaporizable portion on exposure, and also by a process of oxidation, which consists, first, in a loss of hydrogen, and finally in the oxygenation of a portion of the mass."

If it be accepted as true that petroleum and the asphalts are related, as the quotation just made would indicate, then it follows, of course, that any view as to the origin of petroleum also applies to the asphalts. A study of the literature concerning theories as to the origin of petroleum reveals a number which differ fundamentally from each other, and which are based largely upon geological evidence. It does not seem necessary here to give detailed consideration to these hypotheses in view of the thorough manner in which they have been recently summed up and reviewed by Messrs. Sadtler, Peckham, Mabery, Phillips and D. T. Day in a series of papers* read before the American Philosophical Society, February 5, 1897. The comprehensive *résumé* given by Boverton Redwood in his work on petroleum also contributes to make further detailed review superfluous at this time. It seems, however, that the propriety of attempting to make any one of these theories cover the entire question of the origin of petroleum is very questionable in view of the fundamental differences in character and properties between petroleums of different sources, which, by the work of Schorlemmer, Warren, Mabery, Beilstein and Kurbatow, Markownikoff, Schutzenberger and Jonine, Zaloziecky and others, have been shown to exist. The following quotation from Boverton Redwood's work is of interest in this connection.

Referring to his *résumé* of theories, he says: "From the

* "Proc. Amer. Philos. Soc.," **36**, 93.

account given in this section, it will be seen that there has been an abundance of speculation as to the origin of bitumen, and that, in regard to some of the theories, a considerable amount of experimental proof has been forthcoming. Probably, on the whole, the Höfer-Engler views at present have the largest number of adherents, and in respect, at any rate, to certain descriptions of petroleum, are the most worthy of acceptance. At the same time, a careful study of the subject leads to the conclusion that some petroleum is of vegetable origin, and it therefore follows that no theory is applicable in all cases."

When we consider, for example, the striking differences in character between California petroleum and Pennsylvania petroleum, to which Peckham, in a number of different papers, has earnestly called attention, the force of the last sentence quoted from Redwood will undoubtedly be keenly appreciated. Commenting upon the Höfer-Engler theory, Professor Peckham* says: "Dr. Engler, therefore, considers that some change in the animal remains must have taken place in the earth, whereby all nitrogenous and other matters, save fats, were removed, the petroleum being formed from this fat alone by the combined action of pressure and heat, or by pressure only.

"In summing up the evidence as to origin, Höfer expresses the belief that petroleum is of animal origin, and has been formed without the action of excessive heat, and observes that it is found in all strata in which animal remains have been discovered.

"Combining these two statements, we arrive at this conclusion as the Höfer-Engler theory, that bitumens are of animal origin, formed at low temperatures from fats alone by the combined action of pressure and heat.

"Steam is left out of this formula, and it is, therefore, inadequate. There is no evidence whatever that any portion of the crust of the earth has ever been subjected to the combined action of heat and pressure without the presence of steam or hot water, and in my judgment the steam has

* "Proc. Amer. Philos. Soc.," **36**, 106.

been a very potent factor in determining not only the formation, but the transference of bitumens."

The writer, from his experience in the production of asphalts, as already described in this paper, feels like endorsing most heartily the views of Peckham in regard to the necessity of steam as a factor in the production of such asphalts, at least, as have been made the subject of experimental study.

The following is a quotation from Professor Peckham's paper on "The Genesis of Bitumens as Related to Chemical Geology,"* which sums up the most important features of his views as to the genesis of bitumens. The laboratory results which I have so far obtained seem to be quite fully in accordance with the conclusions which Professor Peckham has reached.

"Upon this hypothesis, that bitumens are distillates, all of the variations observed in bitumens of different geological ages are easily explained. The earliest forms of animal and vegetable life are admitted to have been nearly destitute of nitrogen; hence, when these forms accumulated in sediments which, borne down by deposits above them, invaded an isothermal that admitted of their distillation, they must have been distilled, in the presence of steam, at the lowest possible temperature; they must have been distilled under a gradually increasing pressure, the extent of which depended upon the porosity of sediments above them up to the surface. They must also have been distilled under a gradually increasing temperature, which would have been largely controlled by the pressure. While the temperature and pressure would have, in every instance, been the least possible, with steam always present, these physical conditions would, on account of the varying porosity and consequent varying resistance of the overlying mass, have produced very great effects in some instances, and very slight effects in others. As a consequence, we have in natural bitumens, as in artificial distillates, materials varying in density from natural gas to solid asphaltum.

Loc. cit.

"If these distillates proceeded from materials that would yield paraffine, these permanent and stable compounds from marsh gas to solid paraffine remained in the receptacles that nature had provided for them until they were released by the drill. If, however, the distillates proceeded from sediments of a different geological age, containing animal and vegetable remains more highly organized, that would yield different series of hydrocarbons, with compounds of nitrogen, then a very different bitumen would be stored in these receptacles. Secondary reactions would convert these primary distillates into a great variety of substances.

"The contents of the original reservoirs, borne down and invaded by heat, might become involved in a second distillation at an increased pressure and temperature. Fractures of these reservoirs from excessive pressure might lead their contents to the surface along lines of contact of strata or with water containing sulphates, by which an originally pure hydrocarbon would be converted into a sulphur bitumen. A nitro-hydrocarbon, reaching the surface under these conditions, might, by the combined action of evaporation and reaction with sulphates, pass through all the varying degrees of density from petroleum to maltha, and become finally solid asphaltum, and this, through the lapse of time and abundance of material, on a scale of vast magnitude."

While it is true that most of the theories that have been advanced to explain the origin of bitumens have been directly concerned with the liquid variety ordinarily known as petroleum, and seem at least to have been based upon study, whether geological or chemical, of this variety to the exclusion of the solid form generally known as asphalt, still it is true that some theories have been advanced to explain directly the formation of asphalts, aside from and independently of their possible relation to liquid petroleums.

Thus the Trinidad asphalt was looked upon by Wall* as having resulted from the gradual decomposition of vegetable matter found imbedded in it. This view is, however,

* "Q. J. G. Soc.," **16**, 460.

no more tenable than the idea that the material originated from animal remains which have been found clearly indicated from a study of the composition of the asphalt.

When we consider the amount and the character of the strictly chemical work that has been done upon the asphalts or solid bitumens, it must be admitted that they have been decidedly neglected as compared with the liquid form. Even elementary analyses are, in many cases, unreliable, and there is much need of painstaking and persistent study in this field.

When we contemplate the marked differences between bitumens from different sources, it hardly seems reasonable to believe that any one theory as to the origin of these bodies can cover all the actual occurrences. It would seem that heat and pressure, singly and combined, and of various intensities, acting with water, both as liquid and as steam, upon the same fundamental material, whether animal or vegetable, should produce a variety of carbonaceous substances differing from each other quite profoundly in physical and chemical properties. Again, similar or identical conditions prevailing with different kinds of material, whether animal or vegetable, or mixtures of the two, should also yield products of various kinds. When, therefore, we consider the great possibilities of variation in combinations of natural forces, and also equally great possibilities of variation in the nature of the organic material upon which these forces may act, it is not surprising that we find, as we do, in various parts of the earth, complicated and intimate carbonaceous mixtures, gaseous, liquid and solid, which are usually summed up under the general heading, bitumens.

The facts and figures given in this communication speak for themselves. Summed up, they show that three asphaltic substances have been obtained by operations of distillation, primarily in presence of steam from natural animal and vegetable material, both separately and combined. The material obtained from the mixture of fish and wood, and called artificial gilsonite, so closely resembles the gilsonite from Utah that it is impossible by inspection to tell the two materials apart. The material obtained from fish alone also

resembles what has been called (with questionable propriety) elaterite from Utah. While these two pairs of substances differ from each other to a greater or less extent in respect to the various parallel treatments to which they have been subjected, and while they also differ somewhat in chemical composition, as well as in physical solubility, specific gravity, streak, etc., these differences are all *in degree* and not in any single case *in kind*.

I am now engaged in the study of an asphalt known as nigrite, which occurs near the gilsonite of Utah. The differences between these two bitumens are throughout more striking than any that I have observed between the natural and the artificial substances considered in this paper.

In conclusion, I take pleasure in acknowledging the benefit and the satisfaction I have derived from a study of the papers published by Professor Peckham, particularly the two entitled "The Genesis of Bitumens as Related to Chemical Geology"* and "On the Nature and Origin of Petroleum."†

I am indebted to my assistant, Mr. Eugene Leamy, for able assistance throughout the entire work, and to one of my former pupils, Miss Georgia Porter, for the nitrogen determinations.

SWARTHMORE COLLEGE, PA., February 18, 1899.

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* "Proc. Amer. Philos. Soc.," **37**, 108.

† *Ibid*, **36**, 103.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, April 19, 1899.

IMPROVED METHODS FOR THE PURIFICATION OF SEWAGE AND WATER, AS SHOWN IN THE OPERATION OF THE MUNICIPAL PLANT AT READING, PA.

By John Jerome Deery,
Architect and Engineer, Philadelphia, Pa.

The city of Reading, Pa., between 1880 and 1893 considered various propositions to provide itself with a sewerage system, which was found to be necessary by the difficulties encountered, particularly in the low sections of the city, where the seepage from the cesspools had caused trouble and disease. The usual abominations and annoyances of a cesspool city had reached that point where they must be eradicated and a modern method substituted.

In December, 1893, City Engineer S. S. Hoff was directed by the ordinances of the City Councils to prepare a statement of general conditions required, and to advertise for general drawings and specifications, and proposals to carry them into effect. These advertisements were inserted in most of the architectural and engineering journals. As an outgrowth of the request, four engineering and contracting companies complied with such invitation.

The proposals and drawings were submitted to the City Councils of Reading, in January, 1894. The various committees of that body inspected plants in other cities and towns, listened to addresses by experts upon the matter, and after careful consideration the City Councils in joint session accepted the proposition of the Pennsylvania Sanitary Sewerage Company of Philadelphia, in the latter part of March, 1894. Shortly thereafter, the pumping station and its appurtenances were placed under contract with the company. In June, 1895, an additional contract was entered into with the company, for the construction of the purifi-

cation and disposal plant, and the laying of the mains. In short, buildings, machinery, mains, right of way and site for disposal plant were provided by the company.

During 1893 the city employed Gracie S. Roberts, C.E., of Brooklyn, to design a house sewerage system, with directions that it be devised to unite with a proposed pumping station at the foot of Sixth Street. After the plans were completed, the first sewer district was placed under contract, consisting of about 3,000 feet of 54-inch brick sewer, and about twenty miles of terra-cotta pipe sewers and ten miles of terra-cotta pipe house connections. In service April, 1899, there were about twenty-six miles of mains and fourteen miles of house connections.

The general drawings, specifications and detail drawings for the pumping station, and for the purification and disposal station were prepared and designed by the writer, and the work was constructed under his supervision.

PUMPING STATION.

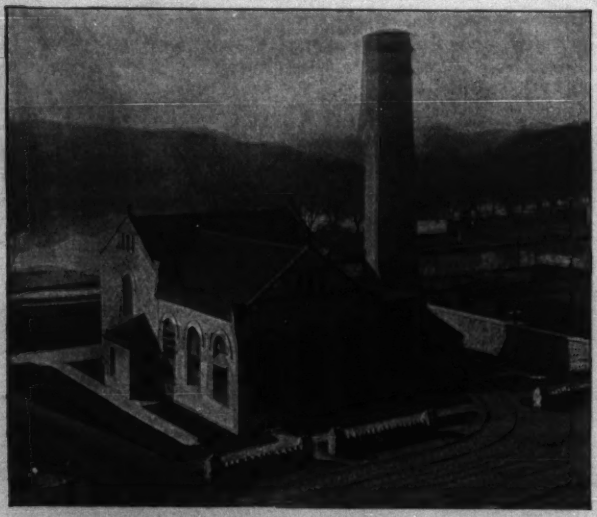
The sewage pumping station is located on a plot of ground on Canal Street near Sixth, and adjoining the Schuylkill River and Canal. It is the lowest point in elevation above the river level, and it enables all sewage to reach the station by gravity.

In the designing of the building and its appurtenances, the site compelled a full consideration of the economy of space and the working facilities. The building covers an area of 76 feet by 70 feet, and extends in parts 20 feet below floor level, and 37 feet above it. The structure contains an office, workroom, lavatory, oil and waste room, engine room, boiler room, coal and coke storage rooms, coke rendering room, smoke and vent stacks, and two sewage-receiving reservoirs.

The boiler room is provided with a set of three horizontal tubular boilers, each of 60 horse-power, with accompanying hot-water well and feed pumps.

The boilers are provided with the coal supply from storage room in front of them, with coal chute doors, thereby keeping coal off floor of boiler room. The coal is brought

into the building on an elevated track from the level of Canal Street, and is dropped into storage room. The boilers have down draught into a 3 x 3 feet flue beneath the floor which connects with the chimney stack. The flue is built of concrete, with a 9-inch lining of fire-brick, and is graded on bottom to the stack. Provision for cleaning out the flue has been made by a vault adjoining the stack, with a dust chamber, so that the soot may be removed



Municipal Sewage Purification Works, Reading, Pa. Pumping station.

either below or on the level of the flue with the aid of a permanent crane on stack for lifting it out.

The pump room has space provided for three 5,000,000 gallon pumps, while at present there are installed two Snow 5,000,000 gallon direct-acting, compound, condensing pumps, connected with an elongated suction chamber, 20 feet in depth, which is joined to each of the sewage-receiving reservoirs. In same room there are also installed two duplex

Municipal Sewage Purification Works at Reading, Pa. Interior of sewage-receiving reservoir, showing distributor, screening floor, air-vents, etc.

surface-condensing pumps, which draw water from a well supplied by the Schuylkill River, and also from the street water-main. The oils and wastes are housed in a non-combustible brick masonry room.

There are two sewage-receiving reservoirs, or screening chambers, each 20 feet in diameter. They are separated by the grease-rendering oven and the smoke and ventilation stack. The stack is arranged with an inner smoke flue, and with outer cluster of ventilating flues.

The sewage flows by gravity from the 54-inch sewer into and across either of the receiving reservoirs, over an open metal trough or distributor, the liquid falling in thin films upon a coke screening bed. These beds are constructed of wrought-iron slats, with upper and lower layers, holding coke breeze or coarse and medium size broken coke to a depth of 12 inches. Over the lower slats is placed a wire grating, ½-inch mesh, of No. 12 wire. These screening beds intercept the grease and coarse floating matter, and the liquid, which is coarsely filtered, drops like rain for 7 feet in the presence of rapid circulation of air into the lower section of the reservoir, whence it flows to suction chamber. Once a week the sewage distributor is pulled, thereby flushing the sewers and depositing its filth on upper crate. After draining for a day the screens are removed in sections. The coke, with all matter adhering to it, is transferred by overhanging crane and tilting bucket into the adjoining brick steam-heated drying and rendering oven.

A constant and copious supply of fresh air is introduced into the reservoirs above and below the suspended screening beds, and it is kept in rapid circulation and removal by special ventilating passages surrounding the smoke flue of the chimney stack, and is discharged into the outer atmosphere at a height of 100 feet. There is absolutely no unpleasant or offensive odor in or around the building from the operation of the plant, and the crude house sewage is purified in these reservoirs to the extent of 25 to 30 per cent. by the aid of light, air and coke-breeze filtration.

The receiving reservoirs are lined above the suspended coke screening beds to grade with white enamelled bricks

and white tiles, and below the screens with vitrified brick, thereby preventing absorption and maintaining cleanliness.

The receiving reservoirs, or screening chambers, have large skylights for illumination and for light as an aid to purification. Appliances and bridges are arranged to facilitate inspection and provide a ready means of cleaning and maintaining the reservoirs in their proper condition. By a series of gate valves, the reservoirs may be used jointly or separately. The reservoirs are in service alternately for a week, and use 7,000 to 8,000 pounds of coke.

When all the coke and sludge matter is removed, the gratings and walls are washed from a hose provided for that purpose under the bridge. Then new coke is lowered into place to form screening bed, and upper grating is reset, as also the sewer inlet or distributor. The reservoir remains in that condition until placed in service.

The drying oven is of brick, having steam-pipes on walls and floors. Through the opening adjoining the reservoirs the coke from screening beds is placed in the ovens. When the coke is dry it is removed through lower door openings and deposited in coal storage room, and is burned as fuel in fire-boxes under the boilers. The small sizes of the coke are shovelled into bags and used as fertilizer. The oven is thoroughly ventilated by connections to the stack and to fire-boxes of boilers.

The building is fireproof in every particular. The exterior presents a pleasing architectural effect. It is faced with light-buff brick, and trimmed with moulded bricks and terra-cotta in the same color. The cornices are of copper and the roofs covered with heavy galvanized iron. The interior is finished in red brick laid in same-colored mortar. All floors are composed of concrete base and granolithic cement surface. Proper provision is made for draining all parts of the building. The earth displaced by the excavation has been formed into an embankment around the building and held in place by riprap facing and stone retaining-walls. The grounds around building are finished off with grass and flower plats. Space is provided for a driveway, which is paved with vitrified brick. All the walks sur-

rounding the building are of cement and concrete composition. A low rustic stone wall has been built along the street front of the site.

The buildings are located within 150 feet of the canal and within 250 feet of the Schuylkill River. The floor level of the buildings is eight inches above the canal level. Innumerable springs were met in the construction of the work, as well as a flood from the river. Portions of the work are constructed below the level of the bottom of the river. The receiving reservoirs have been made watertight, preventing ground water from entering them.

PURIFICATION STATION.

The purification and disposal plant is located 6,600 feet below the pumping station at Millmont, on the opposite side of the river. The site contains eight acres, with access by lane from main road. The site is bounded by the Schuylkill River, the Angelica Creek, the Pennsylvania Railroad and the Philadelphia & Reading Railroad. The latter road has a station adjoining the property, and the former has one at Orrton, one-quarter mile from the premises.

The pumping main is of cast iron, 36 inches in diameter, crossing the bottom of the canal of the Schuylkill Navigation Company, and thence by a 30-inch main of cast iron, laid diagonally in trench across the bottom of the Schuylkill River to the opposite bank. The sizes of these mains are more than ample to permit the pumping through them of 10,000,000 gallons daily. On the other bank the plans call for two lines of 20-inch cast-iron mains, which generally follow the topography of an abandoned canal. One line of the 20-inch main has been set in place, but provision has been made for placing a second line in position when the future extensions and service may require it.

The crossing of the river by the pipe line is 450 feet in length. Trestles were built within the river and platforms placed thereon. The cast-iron pipes were floated and lifted to a point beneath the platform. While in suspension the joints were leaded in customary method, and the entire

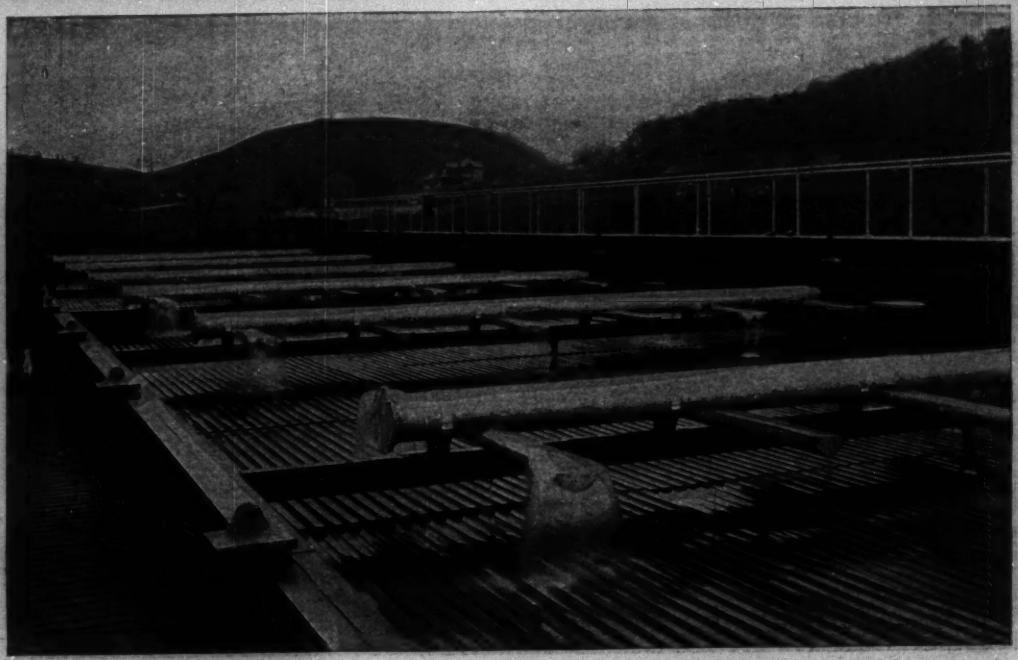
main was subsequently lowered in one length of 450 feet by having a man stationed at each joint of the pipe, who turned a swivel on signal, so that the entire length was laid as one complete pumping main.

The purification and disposal plant is designed to purify crude house sewage, excluding rain and storm water, and after partial purification in screening chambers of the pumping stations, by continuous filtering operation, with the exception of the period when it is necessary to remove the matters in suspension that are held on top of the upper filters. The entire process is based on what is classified as "Slow Sand Filtration by Gravity." It is arranged so as to obtain the purifying action of light, air and scavenger micro-organisms. In fact, it is a home for the cultivation and propagation of those organisms. At the disposal and purification station there have been constructed double filter beds having upper and lower sections with an intervening air space between them of 10 feet, the supporting and dividing parts being entirely of iron or steel.

The lower filter is in one bed, 50 feet x 250 feet, formed over a cement concrete floor, with twenty channels draining the bed into a cement-constructed open effluent channel on outside of structure and parallel to it. Each gutter under beds is 7½ inches at the bottom, 18 inches wide at the top and from 4 inches to 8 inches deep, and is covered with perforated cast-iron grates. At the upper end of each of these gutters are stand pipes extending above the surface and topped with wind guards. This arrangement ensures the circulation of the air to the lower beds and at same time conducts away the effluent. Outside of the structure in each of the twenty channels are set steel disturbers. The lower bed is enclosed with ⅜-inch tank steel, with three rows of channels set horizontally and all bolted to the columns. The joints are covered at the intersection on the columns with sheet-lead gaskets.

The open effluent channel is of concrete, 4 feet wide at the bottom, 6 feet 2 inches wide at the top and 12 inches to 18 inches in depth, and for a length of 650 feet.

The lower filter bed has an average of 8 inches in depth



Municipal Sewage Purification Works at Reading, Pa. Surface of upper section of filter beds, showing distributors, valves, slatted screens, etc.

Municipal Sewage Purification Works at Reading, Pa. Lower section of filter beds, showing water dropping from upper beds, air circulating pipes, etc.

Municipal Sewage Purification Works at Reading, Pa. General view of filter beds, ten compartments; total capacity, 5,000,000 gallons per day.

of broken stone or slag, in layers of sizes from 2 inches to ¾ inch. Over the stone has been placed medium coarse river sand for a depth of 36 inches.

The upper filter is divided into ten compartments for cleaning and renewal purposes, each 25 by 50 feet. It is elevated above the ground and exposed on the top and bottom to the open air. The support of the filter media consists of iron pipes resting upon beams and girders of various sizes and formations, and these, in turn, upon columns, transferring the weight to the foundations in the ground. On this pipe floor is laid broken slag in three layers 8 inches deep, graded in sizes from 2 inches at bottom to ¾ inch at the top. Upon this broken slag, to a depth of 20 inches, is placed fine river or bar sand.

The sewage, or impure liquid, now 3,000,000 to 3,500,000 gallons per day, is brought on to upper filter beds from the pumping main, which extends along the central division of the compartments, with three lines of 8-inch galvanized iron lateral pipes controlled by valves. Each line of the laterals has twelve rows of open gutter distributors, each ⅓ inches deep and 6 inches wide and 3 feet in length, whose surface is about 1 foot above the water level of the filters below them. The beneficent action of light and air is here secured. The water, passing in thin films from these distributors, in its descent falls upon slatted floors, which break up the body of water into spray and small globules, getting by this means thoroughly aërated and prepared for the further purification which is to follow. Over the upper beds is a platform in the center for access to the valves and beds. It is supported on the pumping main. The beds are surrounded by 6 feet wide platforms for workmen and inspection.

The splash plates or slatted floor over the sand serves the purpose of keeping the sand from being blown away when a bed is not in operation, and also allowing it to float so as to be upon the surface of the water and prevent the wind from forming waves, which might be detrimental in any large system of water or sewage purification. As the slatted floors are in sections, they are usually removed after the

water has been cut off a compartment, and the surface of the filter beds, being exposed to the action of air and light, soon becomes thoroughly dry when the gelatinous deposit and sediment upon them, together with $\frac{1}{8}$ to $\frac{1}{4}$ inch of sand, is removed and is placed on sand pile for subsequent cleansing and re-using on beds. Some of the deposit has been used as a fertilizer. Fresh sand is employed to replace the small quantity that has been removed. The body of the beds do not require cleaning or renewal at any time, and seldom require spading or forking.

Usually there is a head of water over the top of the upper filter of about 1 foot in depth, and this, without the aid of any chemicals or pressure other than its own weight, passes through the filtering media. On the surface of the bed is formed a gelatinous product which arrests or stops all matter in suspension. The open elevated filter beds compel the air to be constant in its pressure, both above and below them, thereby ensuring an abundant circulation of air through the beds, and enabling the hardy scavenger organisms to keep in a healthy state of action. They reduce or convert all animal and vegetable matter of a malignant nature into harmless substances, thereby removing all disease-producing organic and inorganic matter.

The water leaving the lower surface of the upper filter passes in drops like rain through the open air a distance of 10 feet, and strikes upon the surface of the lower bed, causing the water to splash and rebound similar to rain upon a roof or pavement. The water, in its descent, is thoroughly aërated, while all gases are expelled into the atmosphere, and should there be organic matter in the globules, it would be burned up or oxidized by its contact with the oxygen of the air.

The water collected on lower bed, dropped there from upper beds, is usually 6 inches to 12 inches in depth. It passes by gravity through the lower filter bed without the addition of chemicals. The beds are supplied with air, having proper inlets and outlets for its circulation, and the gutters are a conduit for both water and air.

[*To be concluded.*]

REPORT OF THE CHAIRMAN OF THE LIBRARY COMMITTEE TO THE FRANKLIN INSTITUTE, MEETING OF JUNE 21, 1899.

The library is one of the most important, most efficient means the institute has for promoting applied science of all kinds. It is highly desirable that the members of the Institute should be kept well informed of the condition of the library and its progress and needs.

The library now contains about 49,600 volumes, besides about 33,500 pamphlets. It receives regularly about 460 periodicals. It is applied to by about 150 visitors a day, of whom about fifty are not members of the Institute, and are chiefly investigators of patents. In addition to applications for reference to books at the library, there are constantly about 175 volumes loaned out to members. For the increase of the library there are: The Bloomfield Moore Fund, yielding about $750 a year; the Matthew Carey Lea Fund, for chemical and physical books, about $150 a year; the Memorial Library Fund, about $50 a year, and the Jas. T. Morris Fund, lately provided by the liberality of Mr. John T. Morris, and soon to be availed of, about $50 a year; making in all about $1,000 a year for the purchase of books. The Board of Managers has appropriated this year $1,500 for the maintenance of the library, of which $500 is more particularly for binding.

The additions to the library during the past two months were 1,223 volumes, besides 584 duplicates, of which about 700 were gifts, including one very handsome gift of about 600 volumes from Dr. Wahl, Secretary of the Institute, and fifty-two volumes and twenty-seven pamphlets were purchased. There are, besides, the weekly, monthly or quarterly parts of periodicals received in exchange for the *Journal* or subscribed for. The binding of the periodicals and other volumes, which had latterly fallen seriously behind, is now gradually getting brought up again. Last year, highly appreciated subscriptions for that purpose were obtained to the amount of about $1,000, and this year the $500 from the Board of Managers will continue the work and enable the current periodical volumes to be bound. If the Board should be able to make an equal appropriation next year, the binding will be fairly well accomplished. Two new regulations have lately been established. For the benefit particularly of those who are studying up special subjects, the number of books that may be borrowed from the library by a member at one time has been increased to four, instead of two. The new additions to the library are now placed on view for a month.

The most pressing present need of the library is a suitable place for the immensely valuable, but, in its present condition, useless, collection of 33,500 pamphlets. There is no room for them in the new fireproof bookstack, and they lie in some confusion in the third story. There are two or three projects under consideration for their accommodation. The most promising, perhaps, is the construction of a fireproof room above the present bookstack; but that would cost several hundred dollars, a great sum for our slender means.

BENJ. SMITH LYMAN,
Chairman.

PHILADELPHIA, June 21, 1899.